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INTERBOROUGH RAPID TRANSIT COMPANY TEST OF SUBWAY ENGINES.

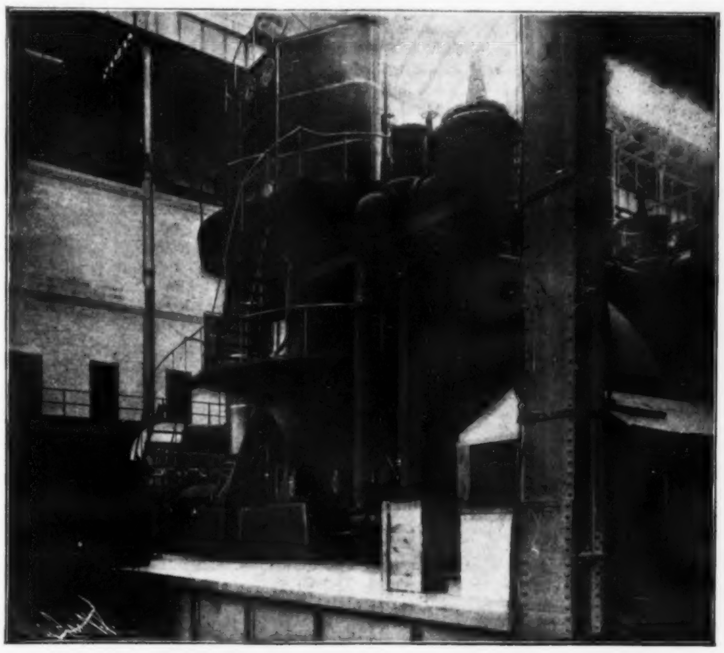
An interesting official fifteen hour test of one of the nine twin vertical-horizontal Reynolds Corliss engines, 42 inches and 86 inches by 60 inches, which have been in operation at the 59th Street station of the Interborough Rapid Transit Company, New York, since 1902, was concluded December 16. The tests were conducted by the Interborough Rapid Transit Company and representatives of the Allis-Chalmers Company as a final determination of the fulfillment of the builder's guarantee as formally provided for in the original contracts.

How well the tests of engine No. 8, which was selected as representing all the engines installed, fulfilled the claims made for it, may be readily ascertained from the following data giving a synopsis of the completed tests.

As per agreement, on account of the impossibility of keeping a constant load, the power was determined by the readings of tested integrating wattmeters. These readings were reduced to I. H. P. by running the generator as a synchronous motor. Adding the electrical input to the switchboard readings when developing power, showed the power exerted by the engine. The result of the test so made, under conditions approximating the contract requirements of 7,500 horse-power, 75 R. P. M., 175 pounds steam pressure and 26-inch vacuum, was a consumption of 11.96 pounds of dry saturated steam per I. H. P. hour, or well within the guarantee of 12.25 pounds. The steam consumption per kilowatt hour at the switchboard was 17.34 pounds.

Duration, 15 hours; Load, 5,079.2 kilowatts; Friction and generator losses, 417.3 kilowatts = 559.41 horse-power; Total load, 5,496.5 kilowatts; I. H. P., 7,365.3 horse-power; R. P. M., 75.02; Steam pressure, 175.18 pounds; R. H. receiver, 19.1 pounds; L. H. receiver, 19.27 pounds; Vacuum, 26.02 pounds (actual); Temp. injection water, 42.36 deg.; Temp. R. H. discharge, 74.05 deg.; Temp. L. H. discharge, 77.38 deg.; barometer, 30.50 inches; Water per hour, 89.906 pounds; Drips per hour, 512 pounds; Leakage per hour (boiler), 1.470 pounds; Boiler level corrections, 60 pounds; Net water per hour, 87.864 pounds; Quality of steam, 100.28 per cent; Dry steam per hour, 88.110 pounds; Dry steam per kilowatt hour, 17.34 pounds; Dry steam per I. H. P., 11.96 pounds.

The final results allow for boiler leakage, which was determined by a



ONE OF THE ENGINES, SHOWING THE BAROMETRIC CONDENSERS.

THE GREAT SUBWAY POWER STATION WITH FIVE OF THE ELEVEN ENGINES AND GENERATORS IN PLACE. ULTIMATE CAPACITY, 182,000 HORSE-POWER.

INTERBOROUGH RAPID TRANSIT COMPANY TEST OF SUBWAY ENGINES.

separate test of twenty-four hours' duration. The steam was very slightly superheated during the test, as being easier to make allowance for than wet steam, and a correction was made to reduce the superheated steam to equivalent dry saturated steam.

The vacuum was carried at 26.02 inches, or as near the contract requirement as possible, but the barometer stood at 30.50 inches. The vacuum was, therefore, equivalent to only 25.52 inches referred to 30 inches barometer; no correction was made, however, as none was provided for in the contract. Other tests at varying vacua show that if the vacuum had been carried enough higher to correspond to 26 inches vacuum when referred to 30-inch barometer, the steam consumption would have been about 0.09 pound better, or 11.87 pounds per I. H. P. hour instead of the official figure of 11.96 pounds.

THE USE OF ALCOHOL AS FUEL FOR INTERNAL-COMBUSTION MOTORS.

Mr. Dan Albone, of Biggleswade, Bedfordshire, England, is the inventor of what is possibly the first agricultural gasoline automobile. At any rate this machine, which has been developed and put to many practical uses about the farm, is one of the few machines manufactured in the world to-day for agricultural purposes. We have illustrated it at different times, so that it is doubtless familiar to our readers. Mr. Albone has been experimenting with alcohol and kerosene as fuel, and he sends us the following interesting description and results of his tests:

Some months ago I was able to arrange a simple attachment whereby kerosene could be utilized for the running of the motor which was originally designed for gasoline, and was able to secure absolutely satisfactory results; that is to say, it is possible for me to either start up on gasoline, and, after five minutes' running, to turn on kerosene and run on same for the rest of the day; or, in case it is impossible to obtain gasoline, it is possible for me to start up on kerosene and run the engine continuously. This, I may say, is accomplished without the slightest trouble in regard to sticking up of valves or fouling of the engine.

My company have, however, in connection with our foreign trade, had demands from time to time for a motor to run on alcohol; and it was with the object of finding out exactly what could be done with alcohol spirit that I have been conducting further experiments in the field.

In the first place, I found the greatest difficulty in getting the alcohol spirit. It does seem an extraordinary thing that it is impossible to obtain alcohol spirit which could be used for fuel in internal combustion engines, because it is a product in the production of which the whole agricultural community in England would derive some benefit.

There are many products of the farm, such as potatoes, beetroot, mangelwurzel, vegetable marrow, apples, wheat, malt, etc., from which alcohol spirit could be obtained, and therefore it does seem to me an extraordinary point that this has not been taken account of before by those who are studying ways and means for the benefit of the English agriculturist.

Of course one of the most important points in connection with motors for agricultural purposes is the fact that they should be run cheaply, that the upkeep should be small, and the running expense light. Therefore the question of fuel consumption and the cost of same is very important. Gasoline at the present time is expensive. It is easy for a wealthy owner of a car used for sporting or pleasure purposes to buy gasoline without feeling in any way that it is a burden to his pocket. At the same time, to the agriculturist using his machine only to help him with his work, the expenditure is an important one. Therefore the first step I took was the utilization of kerosene, which can be obtained at one-half the price of gasoline. This shows a decrease in the running expenditure of one-half for fuel and at the same time does away with the many risks that are bound to occur through the storing and handling of gasoline, which is of the highest specific gravity.

It is a clean spirit to handle and has many other advantages. Therefore, following up my experiments, I used alcohol for the third fuel tests and may say that the same have been attended with most successful results; the same machine with the same carbureter with a very small attachment and with no alteration to it making it different from when it is running with gasoline, gives nearly the horse-power and the same pulling results.

The consumption is practically the same, and I feel that I have to congratulate myself on having carried out experiments so successfully on a fuel which has up to the present time baffled most of the motor engineers in so far as its successful use is concerned.

At the present time alcohol in this country is much more expensive than gasoline, but I think if it can be proved beyond all doubt to those in authority that alcohol can be manufactured and used successfully and that there will be a big demand for it in connection with motor vehicles, that the restrictive duties at present imposed on alcohol spirit would be done away with and a market opened for the product of the fuel which, as I have before mentioned, would be of interminable value to the farmer and to the country.

To set out my experiments in detail I may say that the following results have been achieved with the three fuels running the same machine on the same soil, and in fact the experiments were carried out on the same day.

With 2 gallons of gasoline 3 roods of land were plowed.

With 2 gallons of kerosene 2 roods 35 poles were plowed.

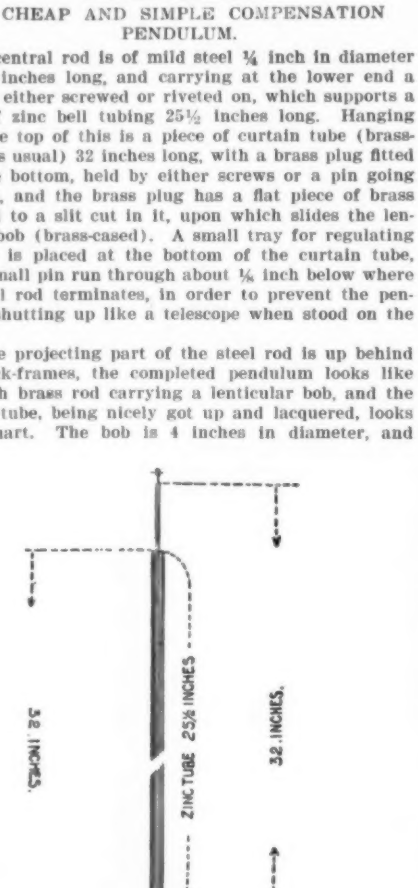
With 2 gallons of alcohol 2 roods 25 poles were plowed.

I think these results are, to say the least of them, very interesting indeed, as showing that there are many possibilities in connection with the motor vehicle which have not been worked out, and personally I consider the successful use of alcohol in connection with a high-speed engine of the utmost value to the industry and to this country.

A CHEAP AND SIMPLE COMPENSATION PENDULUM.

The central rod is of mild steel ¼ inch in diameter and 32 inches long, and carrying at the lower end a washer, either screwed or riveted on, which supports a piece of zinc bell tubing 25½ inches long. Hanging from the top of this is a piece of curtain tube (brass-cased, as usual) 32 inches long, with a brass plug fitted into the bottom, held by either screws or a pin going through, and the brass plug has a flat piece of brass soldered to a slit cut in it, upon which slides the lenticular bob (brass-cased). A small tray for regulating weights is placed at the bottom of the curtain tube, and a small pin run through about ⅛ inch below where the steel rod terminates, in order to prevent the pendulum shutting up like a telescope when stood on the ground.

As the projecting part of the steel rod is up behind the clock-frames, the completed pendulum looks like a ½-inch brass rod carrying a lenticular bob, and the curtain tube, being nicely got up and lacquered, looks very smart. The bob is 4 inches in diameter, and



weighs about 4½ pounds, the rod and tubes about 1½ pound; but no doubt the zinc tube would easily carry a bob twice as heavy. I used this one because it brought the pendulum to the same weight as the wood and lead I had been previously using. And it may be well to remind those who may make a similar pendulum that, as the tubes form such a considerable portion of the weight of the pendulum, the center of oscillation is considerably above the center of the bob—in this case quite 3 inches—so they must remember to make the pendulum quite 42¼ inches long from bending-point of spring to center of bob when the bob is well screwed up. A few small holes down the sides of the curtain tube to allow free access to the zinc tube would be beneficial, though I have not got them, and possibly the zinc tube might be better a bit longer; but I am not satisfied that the compensation is under the mark—a careful scrutiny of the rates I sent leaves it open to doubt. And the following extract from rate-book seems to leave it still doubtful:

	Error from G.M.T.	
1903. Jan. 8	+10sec.	
12	+11½	Very cold, and arc of pendulum visibly reduced.
17	+13	
26	+13½	
31	+12½	
Feb. 7	+13½	Very mild
11	+13	

—English Mechanic.

BENJAMIN FRANKLIN AND ELECTRICITY.*

One notes a tendency among certain physicists to return to Franklin's one-fluid theory of electricity, and to identify his electric fluid with the ether. This tendency is seen, perhaps, more strongly in England than on the Continent, and it is accompanied by an idealistic trend of thought which forms one of the most remarkable reactions between physics and metaphysics. It naturally leads one, on this anniversary of his birth, to examine his work in electricity, and to comment upon the attitude of the philosophers who seize the present confusion of physicists in the presence of radium and the mysterious phenomena of the X-rays to proclaim the ultimate reversion of the thinking world to an idealistic conception of matter and energy.

It is not often that a scientific man can appeal by his experiments to the whole human race so that, from the most ignorant to the most cultivated, the experiments become household lore. Franklin, we have believed from our infancy, drew the thunderbolts from the sky; in our minds he is the incarnate Prometheus. His kite experiment was dramatic, and the setting of the stage more impressive than an Irving could accomplish. Great cumuli, formed, like the fisherman's genie, out of thin air, darkened the heavens, and flashing with ire, came on the rising wind to the accompaniment of thunder. The calm philosopher stood with bared head at the center of the stage, and, by his renowned action, stirred to life the Promethean myth—the strange myth which seemed to foreshadow the relinquishment to man of a celestial fire. Without detracting from his philosophic insight, it can be said in passing that his safety in making the kite experiment is one of the most convincing examples of luck on record. An immediate follower of his example was killed, and to-day no one, even a boy, would dare to repeat the experiment. Instead of being covered with opprobrium for what the common-sense Yankee still calls "monkeying" with lightning, he became the greatest electrician of his age, thus uniting a command over one of the most subtle manifestations of nature to his influence over "that fiery particle, the mind of man." His kite experiment led to a renewed interest in experiments with Leyden jars and electrical machines—experiments which were not due to him alone, but which were brought into notice by his dramatic experiment. The fashionable world of Paris amused itself with electrical experiments; and, instead of playing bridge, the court ladies stood on insulated stools and gave sparks to adoring courtiers. In most colonial houses, fifty years ago, there was a popular engraving representing Franklin at the court of Louis the Sixteenth, being crowned by the ladies in the presence of a brilliant assembly of courtiers. Artists painted him gazing out of the canvas with that imperturbable smile "o'er all the ills of lightning victorious," while forked flashes were seen through the open window.

When we examine Franklin's work in electricity, we discover that the results of his experiments and the repetition of those of foreign investigators are embodied in his one-fluid theory—a theory which seems to have been given a new lease of life by the modern theory of the negative corpuscle. In Franklin's view, the negative state of a body was explained by a deficit of a fluid. The negative-corpuscle theory accounts for it by the detachment of a negative corpuscle from a positively charged body. A positively charged pith-ball shows a negative state when the negative corpuscles are detached, in comparison with a positively charged pith-ball which retains its full complement. We can picture to ourselves a species of electrical vacuum thus created between the balls. The electrical condition of the surrounding space is disturbed and the balls are forced together. This statement merely expresses what takes place, without giving any illuminating reason for the action; and we have to confess that we are no nearer a decision between the claims of the one-fluid theory and the two-fluid theory which was in vogue before Franklin enunciated the former, than the philosophers were 200 years ago. The truth is, that Franklin got hold of the hardest end of electricity, and could not make much progress. His experiments were interesting, but did not really lead to the great development of electricity seen in the nineteenth century. The electric spark may be said to contain the whole potentiality of electricity. During 200 years we have learned little more than Franklin knew about it; and it must be confessed that our study of lightning has not conduced to the great development of practical electricity. Indeed, lightning is still a terror and an impediment to electrical enterprise. It was reserved for that remarkable race, the Italians, through Galvani and Volta, to open a more fruitful method of studying the phenomena of electricity. Without the battery, Franklin's results would have remained on a par with the philosophic observations of the Greeks—somewhat more extensive, but food for philosophy rather than for science, being devoid of measurement. Without measurement, science cannot advance beyond the wild surmise of the philosopher. It must be said, however, that Franklin had the merits of an early explorer, and doubtless excited the imagination and increased the interest in the subject of electricity. The explorer on the Peak of Darien, gazing on the mysterious ocean spread before him, doubtless thought of Eldorado, new peoples, and wonderful products of new climes. As long as philosophers worked with electrical sparks without measuring instruments, their vision did not include an electrical Eldorado.

Franklin had a clear sense of the universality of the manifestations which he studied; and when Mr. James Alexander, of New York, suggested that the velocity of electricity could be measured by allowing it to run down certain rivers and to work its way back by other water-courses, Franklin showed clearly that all parts of such a circuit would respond instantly to an electrical stimulus. He evidently believed, however, with Mr. Alexander, that electricity would follow the water-courses instead of being instantly dissipated in the earth; for he ranked water with metals in respect to electrical conductivity.

When we class Franklin with the non-measuring philosophers, we shall be asked, "Did Faraday ever

* The Nation.

make a quantitative measurement?" and we can answer that Faraday had essentially a mathematical mind, which did not express itself in symbols: he was a scientific poet without the rhyme. His mathematical conception of lines of force forms the basis of the most mathematical and the best treatise on electricity ever published, Maxwell's treatise on electricity and magnetism. We propose, therefore, to class Franklin among philosophers who have condescended to study nature—the type which has a *raison d'être*, but which is not the best working type, for they have not the essential tools. His principal work in electricity resulted in the formulation of the one-fluid theory which we may class as a philosophical production, not engendering any unanimity of belief; and in the kite experiment, with the application of the result to lightning-rods. Even to-day there is not a realizing sense of the amount of energy which is often manifested in a lightning discharge, and which no lightning-rod is competent to carry to the ground. The early experiments with glass electrical machines and with Leyden jars, and the celebrated kite experiment, gave an erroneous impression of lightning. Timid people still seek safety in a thunderstorm in featherbeds, sit on chairs provided with glass legs, stand on plates of glass, or feel confidence in rubber boots. A moment's reflection will convince us that a discharge of lightning often many hundred feet in length cannot be prevented by a few inches of glass or any insulator. It would be highly unsafe to repeat Franklin's kite experiment if one stood on a plate of glass in proximity to the string, for lightning exhibits a side flash. From the fact that Franklin was not killed, certain electricians believe that he did not actually draw lightning from the skies, but merely showed that there was a difference of electrical state between the higher regions of the sky and the ground. On many days under a clear sky one can obtain sparks from a kite string suitably conducting. It was reserved for Faraday to show that the only complete protection from lightning is a metallic cage.

I should soon lose the attention of the general reader if I endeavored to develop at length the theory that all matter is electrical, and that it consists of knots in the ether. This theory is based *au fond* on what is termed electric inertia—that is, the disposition of an electric current to continue when the circuit, or wire carrying it, is broken, and to resist starting when the circuit is made, or the ends of the connecting wire are coupled with the dynamo or battery. This illustration of something resembling the inertia of matter is not a very scientific one, but it perhaps enables one to grasp the idea that the reactions between currents of electricity formed in space might cause the inertia which enables us to conceive of matter. The attitude of physicists toward this electrical theory of matter is simply this: Let us see how far a mathematical treatment based upon this new conception will carry us, for in this analysis we may be able to clarify our views without committing ourselves finally to a theory which seems at first sight to be so opposed to daily experience, a theory of no matter. Franklin, in his one-fluid theory, did not identify electricity with possible motions or knots in a universal ether. He held fast to the usual conception of matter, something that you could hit your head against; and he conceived of a subtle fluid, the electric fluid, which was contained in different proportions in all bodies. The particles of the fluid are supposed to repel one another, according to the law of the inverse square of the distance, and to attract those of matter according to the same law. Those of matter are supposed to repel each other and attract those of electricity. We have, then, cases of surcharge and cases of deficit, which are analogous, perhaps, to conceptions now much in vogue in England, and which arise from the theory of the negative corpuscle.

The power of words has never been more strongly exemplified than by the effect on mankind of the celebrated line of the Frenchman, "Eripuit cœlo fulmen, sceptrumque tyrannis." I have analyzed the major part of this proposition, and I leave the minor part to the historians.

JOHN TROWBRIDGE.

EFFICIENCIES.*

By JAMES SWINBURNE.

THE term "efficiency" is used by serious people to denote the rate of the useful part of the energy or power obtained, to the energy or power put in. There is another aspect of the question, and the term "efficiency" may be stretched to cover questions of money. For instance, if in a bargain you get 15s. worth of goods for £1 the purchase may be said to have an efficiency of 75 per cent. But in cases of this sort it is not quite usual for a bargain to have an efficiency of more than 100 per cent from each point of view. This is because in the case of a well conducted bargain, each of the parties, to use a legal word, gives what he prefers to part with for what he wants more; so that both are satisfied. But the seller may take another view; he may have bought an article for 15s. and sold it for £1. In that case he apparently makes 5s., and it might be called 33 per cent of the cost price, or 25 per cent on the selling price. The term "efficiency" is not applied to such cases, because "efficiency" is employed in cases where there is a partial loss, to show how much has not been lost. Cases of profit would be cases of efficiencies of over 100 per cent. A trader who looked upon buying at 15s. and selling at £1 as making a profit of 33 per cent, would really be deceiving himself, because in such cases it is not really a question of how much is made over and above the apparent purchase price, but of what profit is made per annum on his trade capital. Into this question all sorts of considerations enter, that do not appear in the statement of simply buying and selling. If he is merely a trader who buys and sells he has to pay rent, incurs bad debts, loses stock through depreciation and other causes, and has to give his time to the work. He also may have to spend a good deal on advertising.

Another simple case is that of manufacturing. If an engine builder, for example, spends £1,000 on wages paid to men who have made an engine, and £1,000 for material, and sells an engine for £3,000, it is commonly said that he has no business with the odd £1,000; either he is said to have overcharged his customer £1,000, or he has robbed the workmen of £1,000, as it was their work that made the engine. Both these notions arise from ignorance; and this ignorance, like all other kinds of ignorance, does a great deal of harm. The argument that all the money paid to manufacturers should go to workmen who actually make the goods is always employed by the agitators who live by stirring up the passions, and flattering the weaknesses of their victims. It may seem strange to bring forward such questions in an address to electrical engineers; but I want to urge the importance of looking at things from a money point of view, because all engineering is a question of money; and I want to bring some money questions as well as energy and power questions before you to-night.

In making any bargains with Nature, we always lose in a sense; and we are so accustomed to it that we take it quite contentedly, and merely try to lose as little as possible in the transaction. As I said before, the relation of what we do not lose to the whole is termed the "efficiency." In dealing with our fellow men we always hope to make a profit, and we sometimes do. In such a case it might be correct to talk of an efficiency of over 100 per cent, but it would be unusual. It might be still more unusual to say a bankruptcy which resulted in a payment of 6s. 8d. in the £ was a transaction with an efficiency of 33 1/3 per cent. But there would be enough justification for such a proceeding to enable me to discuss some aspects, even of electrical commerce, under the head of "efficiency."

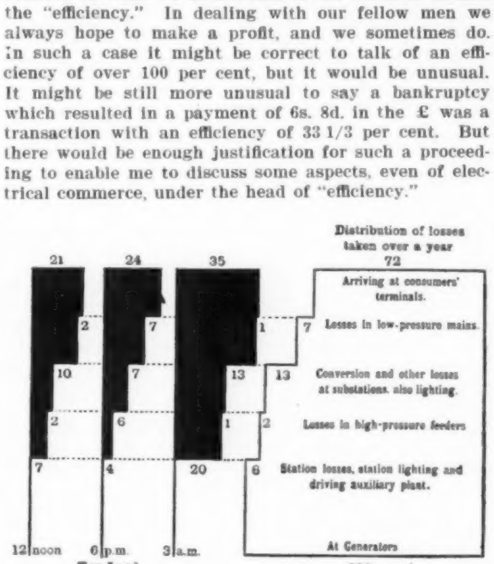


DIAGRAM ILLUSTRATING LOSSES ON THE METROPOLITAN ELECTRIC SUPPLY COMPANY'S SYSTEM.

Heat includes what is called sensible heat, or heat that makes things hot; latent heat, such as the heat that disappears when ice is melted or water vaporized at constant temperature; and chemical energy. I must tell you that it is not orthodox to call chemical energy heat; and you will not find any such treatment of the subject in books on thermo-dynamics. At present I believe I am alone in classing chemical energy or defining heat so as to include chemical energy; but the treatment of chemical energy in chemical thermodynamics is quite consistent with my definition, so I may use it provided I give you due warning of any heterodoxy. I think that it is not realized that chemical energy is necessarily low-grade energy, only partially convertible into work. This involves the idea of chemical temperature which may be important in chemistry in discussing the way any given possible reaction will go; but we are not concerned with that here. It will be said that the coal is cold when it is put into the furnace, as cold as the air in fact; so that if this idea is right none of the chemical energy is available. But I must give some idea of what I mean by chemical temperature. If carbon and oxygen are heated to a high enough temperature you get a state in which on the least fall of temperature the carbon and oxygen combine and give out sensible heat at that temperature, under the other circumstances that obtain. The least increase of temperature, however, causes the carbon and oxygen to separate again, absorbing sensible heat. At this temperature, therefore, under the pressure and quantitative relations of the carbon, oxygen, and carbon monoxide, sensible heat and chemical energy are interchangeable. This temperature may be called the chemical temperature of the energy of carbon and oxygen. I need not trouble you with discussions as to whether the energy is really in the carbon or the oxygen or the ether, or as to the effect of pressure and proportions of carbon oxygen and monoxide on the reaction. I merely want to give you a broad idea of carbon as having or controlling chemical energy, or heat with a corresponding "chemical temperature" of the order of 3,000 deg. C. or more. If the burning coal, containing, of course, other constituents, such as hydrocarbons with other chemical temperatures, could hand over their heat at 3,000 deg. C., nearly all of it would be available. As the heat is finally rejected at condenser temperature of 100 deg. or so, 3,000 less 100/3,000, or about 97 per cent of it, would be available. But the boiler takes it up at under 500 deg. C. absolute, so that five-sixths is degraded or rendered unavailable right off.

It might be supposed that there is enormous room for improvement in the steam engine. An efficiency diagram looks as if all the loss is due to the engine which gets 68 per cent and only gives out 7 per cent, but we must not be hard upon the engine. It is turning out work, or high grade energy, and it is receiving heat, or low grade energy. This engine is probably taking in steam at about 450 deg. C. absolute, and rejecting it at about 375 deg. C.A., so it could if perfect only turn out $68 \times 75 \div 450 = 11.3$; so it is not really doing so badly. The real loss is between the fuel and the boiler, and it is not loss of energy, but loss of availability. Though the chemical is low grade energy, it has such a high chemical temperature that 97 per cent is theoretically available; but we cannot run a boiler and engine between 3,000 deg. C. and 4,000 deg. C. Engineers are always trying to improve the results by using higher and higher temperatures; but as you cannot use the pressures that would then correspond with saturated steam you can only superheat. This does not mean that most of the heat is taken in at the high temperature, and the resulting gain is chiefly due to such things as reduction of cylinder condensation. There are great practical difficulties in reducing the lower temperature. The condenser reduces it to about 100 deg. C. or 373 deg. C.A.; but even then the steam is not completely expanded, and blows into the condenser under pressure. The efficiency has been raised more recently by reducing the lower temperature limit by means of sulphur dioxide. I do not know who was first to propose this. Rayleigh suggested it as early as 1876. It is being put in practice now in Germany.

At this stage I would like to say that this is given as an address in my own name because I was asked to give an address. If it had been a paper, Mr. Walter Claypool, lecturer on electric lighting and power distribution at Croydon Central Polytechnic, would have been joint author nominally, as well as in reality. I am indebted to him for all the hard work.

The right hand part of the accompanying diagram illustrates the yearly losses in the Metropolitan system, supplying several London areas from Willesden. I am indebted to Mr. Highfield for the figures. It will be seen that the transformers are very efficient, and when they can be cut out at light loads so that the transformers in use are always well loaded, the efficiency can be made very high. The diagram is also a little deceptive because it takes no notice of the time at which the energy is wasted. Energy wasted at the time of station full load is serious, because if it were not wasted it might be sold, or else the station might be a little smaller in proportion. But most of the waste in transformers is of light loads, and it costs very little extra to generate extra power at times of light load, for it costs nothing extra in capital, superintendence, or labor, and it does not cost much in coal, for the boilers have to be kept hot, and some engines have to be kept running in any case. These points have to be borne in mind in considering the meaning of each diagram. It will be seen that there is a loss of 6 per cent in "station losses," only 2 per cent feeder losses to sub-stations and 13 per cent conversion losses and lighting of the sub-stations.

These are for the year. They alter from time to time, so the wastes are shown black to the left for three representative times. Thus the station losses are 7 per cent at noon, 4 per cent at top load, and 20 per cent at three in the morning, and so on. This is because the losses do not vary in proportion to the loads. Through the various sources of waste energy, the final result is that there is 21 per cent loss at noon, or 79 per cent efficiency and 74 per cent efficiency at 6 P. M., and up to 65 per cent at 3 A. M., which is astonishingly good when the system is considered.

If a station is run by a town the accounts must be kept by an absurd system. Towns are generally concerned with such things as sewage systems, in which there is no profit and loss account. The town may not treat its sewage system as a permanent asset at all. It has to borrow money to put down its sewage system, say £100,000 at 3 per cent. Then it has to pay £3,000 a year interest. But that is not all—it has to pay back the whole of the £100,000 in a certain number of years. To do this it has to provide out of the rates a sinking fund, such that in the prescribed term of years the whole of the debt is paid off. The town then has a sewage system to the good, which has been paid for over many years out of the rates. The town therefore does not save money like the private individual and then buy what it can afford. I do not think it would be allowed to do such a rational thing; it has to borrow money for everything and pay it back over a term of years. The length of the term has no reference whatever to the nature of the work done, as the work is not in any way security for the loan; the local rates are the security. There is an epidemic of outcry just now about municipal indebtedness, but it is apt to give a totally wrong impression to the average reader, as he does not realize that municipalities must be in debt owing to the way these things are arranged. For a private individual always to be in debt would be bad; for a town it is another matter; the only question is how much the town ought to be in debt. The nation itself does business in the same sort of way; it has no ready money, and when anything has to be done it borrows. But local authorities are now taking up

* Abstract of an address delivered to the students of the Manchester Local Section of the Institution of Electrical Engineers.

such business as electric supply and tramways, which have profit and loss sides; but they are obliged to work the business on the same lines as town improvements, which is absurd. A municipal electric light scheme is thus worked under absurd difficulties. It is like a public company that has a negative capital—that is to say, all its money is borrowed. The shareholders are the ratepayers. They hold shares depending on the rate assessments. The dividends are generally negative. All the shareholders are so by compulsion if they live in the place. The only thing they can do if they do not want to be shareholders in such undertakings is to move off to another town; but then they become shareholders in another set of ventures. I believe the only way to avoid being shareholders in these compulsory undertakings is to live in a barge on a canal. Be this as it may, the undertaking, though a profit and loss concern, must keep its accounts on the same principle as if it were a sewage system. To begin with, the town may only borrow enough money to put down the plant. This has to be paid off, as already explained, by the sinking fund, which returns all the borrowed money in, say, twenty years. The plant may last ten years, or it may last fifty; that has nothing to do with the case. If the plant lasted twenty and then went into powder, like Holmes' "one-hoss shay," the sinking fund would correspond with correct depreciation. If it lasts less, something more should be allowed, and less should be written off for the parts that will last longer. This right depreciation to be allowed in municipal works is a burning question between the advocates of municipal trading and its opponents. Again, a private concern would start business with enough capital to put down the station, and to run it at a loss for a year or two until it turned the corner. The municipality may not do anything as sensible as that; it may only borrow

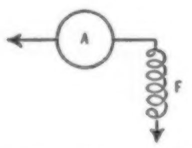


FIG. 1.—SIMPLE SERIES MOTOR.

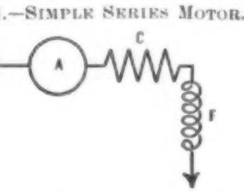


FIG. 2.—SERIES MOTOR, WITH SERIES COMPENSATING COIL.

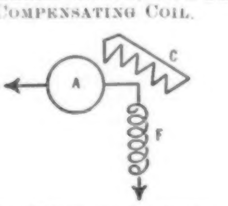


FIG. 3.—SERIES MOTOR, WITH SHORT-CIRCUITED COMPENSATING COIL.

A, armature. F, field. C, compensating coil.

money enough to put down the station, and the first few years' losses must be paid for out of the rates for these years. This sometimes excites the ratepayers. Almost any business has to be run at a loss at first, and enough capital is provided to meet the deficit, and when the business pays it ought to pay on the whole capital. No one would think of starting, say a works, with no working capital at all, and distributing a negative dividend during the next few years to pay the losses. This is one of the many absurd conditions under which municipal work has to suffer. In one case a lovingly solicitous gas company felt that it was hard that a municipality should lose during the first years, so it got a clause inserted to the effect that if there were a loss the price should be raised and raised until there was either no loss or no customers; it did not matter which, though in its heart of hearts the gas company preferred the latter. This clause was solemnly inserted in one or two acts by the collective wisdom of the country. It may interest you to realize that the large commercial interests of this country are controlled by a set of people who think that if a manufacture does not pay, the simple expedient of raising the price will put things right.

Referring to the comparative costs of different artificial illuminants, if electrical energy costs 4d. a Board of Trade unit, an ordinary glow lamp will give nearly 800 candle hours for 1s. A flame arc with energy at 3d. gives you 14,000 candle hours. It must be remembered that the 1s. is all spent on energy, nothing is allowed for renewal of lamps, interest on fittings, meter rents, interest on arc lamp, cost of carbons or labor. For 1s., with energy at 5d., you get about the same light as with a flat-flame gas burner and gas at 4s. The ordinary oil lamp, with paraffin at 8d. a gallon, beats them both hollow, and it is out of the running with acetylene. The great fight between electricity and gas has been fought with flat-flame burners and carbon lamps, and there has been much discussion. I have been accused of a strong partiality for electric light; but I feel impartial; I really do not know which is the worst. The gas mantle makes an enormous difference, and brings gas, say, at 3s. ahead of everything but the mercury and flame arcs at, say, 4½d. a unit. The flame arc is essentially for large lights, while the mantle lights can be made quite small. The comparison is, I repeat, only for the same money paid for gas or energy. To make a real comparison many other factors are to be taken into account. There is the interest on the mercury lamp for one thing; then its color is not good; and if you add carbon lamps the efficiency goes down. On the other side, however, you have to estimate the cost of mantles, the trouble and worry of breakages, and of the jets getting stopped up, and so

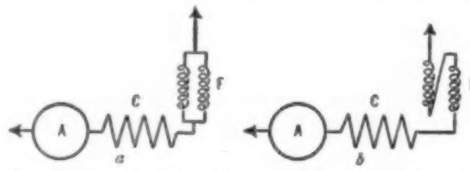


FIG. 4.—SERIES MOTOR WITH FIELD ARRANGED (*a*) FOR A.C., AND (*b*) FOR D.C.

on. Even then it must be clear that the mantle has a large margin of economy for the house lamps, such as the Nernst, the metal and the carbon incandescents. For outdoor use, and for large buildings, the flame arc seems to have plenty of margin over the mantle, though large mantle lamps are even better than some of the smaller ones.

In addition to the cost of lamps, mantles, etc., we must remember that if an illuminant spoils the decorations the extra cost of redecorating should be charged against it. Gas blackens the ceilings and destroys paint, and so on; and the extra cost of decoration may be as heavy as the whole cost of electric light, in which case it does not pay to employ gas at any price. This argument annoys the gas industry, so it is sound and good.

SINGLE-PHASE ALTERNATING-CURRENT RAILWAY WORK.

By LIONEL CALISCH, Assoc. City Guilds of London Institute.

IT is well known that electric railways and tramways are operated, by direct current, at a voltage of about 600. For heavy service, extended systems, and long-distance main line work, the cost of copper, sub-stations, etc., becomes enormous under these conditions. For the generation and transmission of electrical energy, alternating currents are principally used; transformers and rotary converters are required for changing the alternating into direct current.

Of course, a higher voltage than 600 direct could be employed, and the line losses and cost of copper reduced. Experiments on high-voltage direct current railway work have been carried out by Thury in Geneva; but practice has proved that about 600 volts is the best pressure for direct current working, and this is now taken as a universal standard.

Obviously, there would be a great advantage in a railway equipment which could be operated from an

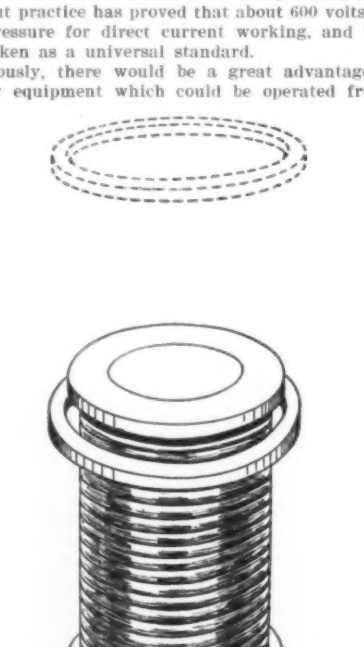


FIG. 5.—TO ILLUSTRATE ELIHU THOMSON'S EXPERIMENT ON ELECTRO-MAGNETIC REPULSION.

alternating current, high voltage supply without the use of rotary converters. For the last nine or ten years engineers have tried to solve this problem by means of the three-phase motor; at present a few three-phase railway systems are in use on the Continent, but, on the whole, three-phase motors are unsuitable for railway work (except in special cases such as mountain railways—for instance, the Jungfrau railway) for the following reasons:

A three-phase motor is a constant-speed motor; that is, the speed remains practically constant with change of load. In a successful railway motor, on the other hand, the speed must vary with the load.

Another disadvantage in the three-phase system is that it necessitates the use of two trolleys, and that the speed control is difficult and cumbersome.

As several articles have been written on this subject during the last few years, I need not dwell any longer on three-phase motors.*

Enormous progress has been made during the last two years with single-phase commutating motors; some lines in America are now being equipped with these, while one is already in commercial operation.

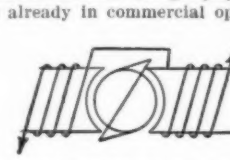


FIG. 6.—ELIHU THOMSON'S REPULSION MOTOR.

Single-phase motors may be classified as follows:

1. Synchronous motors.
2. Induction motors.
3. Commutating motors.

Commutating motors may be divided into (*a*) series motors, (*b*) repulsion motors.

The first two types are entirely unsuitable for railway work, as the starting torque, efficiency, and power-factor are poor, while speed regulation is very difficult.

Reference, however, should be made to the Oerlikon Company's experiments; this company uses single-phase induction motors working at 15,000 volts from a trolley. The motor drives a direct current generator,

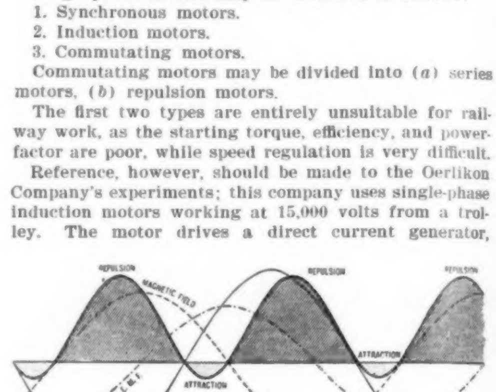


FIG. 7.—TO EXPLAIN THE PRODUCTION OF ELECTRO-MAGNETIC REPULSION.

which in turn supplies current to direct current motors. It is, however, unlikely that this system will be extensively used, as it is too costly and cumbersome.

It is to the last class of motors that we must look for the solution of the alternating current traction problem.

COMMUTATING SINGLE-PHASE MOTORS.

Series Motors.—Since a direct current series motor runs the same way, whichever way its terminals are connected up, it is obvious that such a motor will run with an alternating current. Direct current series mo-

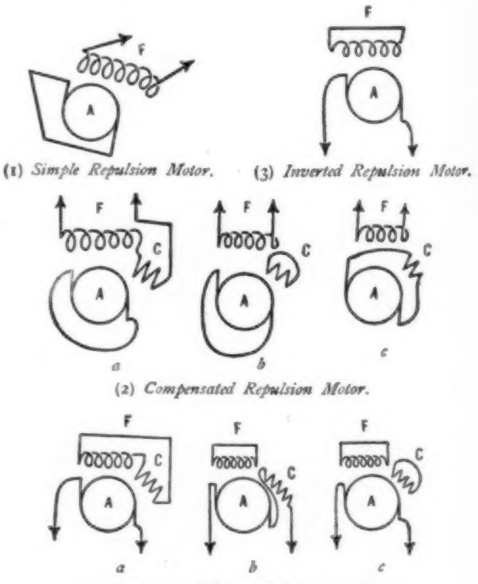


FIG. 8.—TYPES OF REPULSION MOTOR.

tors were used many years ago for alternating currents by simply laminating the pole pieces.

Owing to the high frequency of the currents supplied at that time (from 60 to 133 ~ per second), bad results were obtained on account of heavy sparking at the brushes, so that it was found impossible to construct motors above 5 horse-power.

Several of these small alternating current series motors were at that time in use on the Continent for driv-

* See Eborall, Institute of Electrical Engineers, vol. xxxiii., p. 315.

ing small pumps, etc., and behaved very much like ordinary D.C.* series motors. After many years the series motor has now once more come to the front; it has been greatly developed by Lamme and Steinmetz in America, and Finsi in Italy, and is now used for traction purposes.

A paper read by Steinmetz, before the American Institute of Electrical Engineers,† contains the results obtained by him and Mr. Eickenmeyer with alternating current series motors; from this it appears that an alternating current series motor suitable for railway purposes was being developed as early as the year 1891. Fairly good results seem to have been obtained,

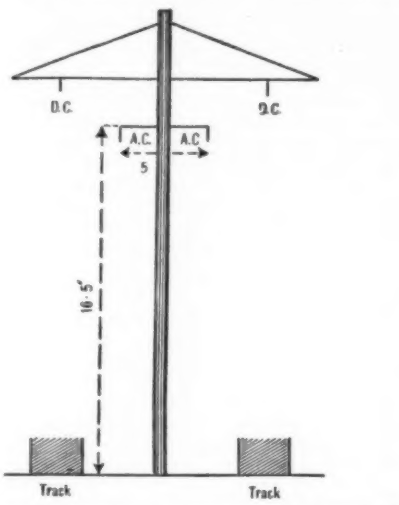


FIG. 9.—TO ILLUSTRATE COMBINED D.C. AND A.C. EQUIPMENT ON THE BALLSTON-SCHENECTADY LINE.

and it is surprising that the work was not continued.

The chief troubles connected with the earlier A.C. series motors were due to sparking, but by the use of lower frequencies now in use (25 ∽ per second) and the application of our present knowledge in regard to commutation and electrical design, machines have been built which do not spark excessively. Heavy currents are induced in the armature coils when they are short-circuited by the brushes, and these currents must be broken when the coils pass from under the brushes, and excessive sparking and demagnetization of the field are produced. To reduce these currents somewhat, Lamme and Finsi use high resistance connections between the armature coils and commutator segments, which considerably improve commutation.

The power factor (a feature which does not need to be considered in direct current machines) is another important consideration. In the simple series motor (Fig. 1) the power factor is very low, because the armature and field windings in series with it offer a great impedance to the alternating current passing through them. The greater the current, the worse is the power factor; so that at starting the power factor is very low, but increases with the speed.

The efficiency of the A.C. series motor is not quite so high as in the D.C. series motor, on account of the iron and copper losses, which are considerable.

To overcome the difficulty of bad commutation and low power factor, Eickemeyer, as early as 1891, introduced the compensating coil, which lately has come to the front again. The object of the compensating coil is to counterbalance the self-induction of the armature. Compensation may be effected in two ways: (1) the compensating coil may be in series with the armature and main current (Fig. 2); or, (2) the compensating coil may be short-circuited (Fig. 3), and acts as the short-circuited secondary of a transformer of which the armature is the primary. The current in the compensating coil is in opposition to that in the armature, and counterbalances the self-induction of the latter. The effect of this is to improve commutation and increase the power factor. It also slightly de-

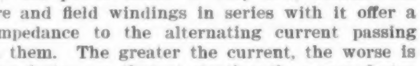


FIG. 10.—TO ILLUSTRATE METHOD OF SUPPORTING TROLLEY WIRE.

creases the efficiency. Such a compensated motor has the true series characteristic, and can be operated equally well either on direct or alternating current supply.

The enormous advantage of the series motor is, that it can be operated either with A.C. or D.C. supply; thus it is possible to use the same motor on a line fed with D.C. and on another line fed with A.C.

In operating series motors on D.C. and A.C. supply, it is found that the best proportion for the field-windings for D.C. and A.C. running are different. The General Electric Company of Schenectady winds the field in two sections, which can either be thrown in parallel or in series (Fig. 4). For alternating current the sections are in parallel, because this gives a smaller self-induction; for D.C. running they are thrown in series. A properly designed compensated series motor, when running D.C., has almost perfect commutation; in fact, this is much better than in any ordinary railway motor, since the compensating coil balances the field distortion of the armature, and thus acts like the Ryan balancing coil.

Several articles have been written on the most suitable field construction. Osnos (see Zeitschr. Electrotechn., Wien, 21, pp. 711-717, December 27, 1903, and Science Abstracts, vol. 7, No. 569, p. 219) has gone very fully into this question; he prefers the distributed winding, just as in an induction motor field, while Heubach, in his treatise "Der Wechselstrom-Serien Motor," arrives at the conclusion that the field winding should be as in continuous current motors, the poles being of course laminated. This question, however, does not seem settled. The Westinghouse Company uses laminated poles and field windings, as in an ordinary D.C. series motor, while the General Electric Company uses a winding distributed in slots, exactly like the stator of an induction motor.

Repulsion Motors.—Between the years 1884 and 1889 Prof. Elihu Thomson carried out a series of important experiments on electromagnetic repulsions and rotations produced by alternating currents. One of the best known, and at the same time the most fundamental of his experiments, is that of throwing a closed metallic ring in the air by means of an electromagnet excited by an alternating current. A powerful electromagnet (Fig. 5) has a core consisting of a bundle of iron wires. As soon as the electro-magnet is excited by means of a powerful alternating current, the copper ring shown in Fig. 5 is thrown up in the air, on account of the strong repulsive force exerted on it by the magnet. Under favorable conditions the ring may be thrown from twenty to thirty feet high.

These experiments led to the construction of Elihu Thomson's repulsion motor, which was shown at the Paris Exhibition in 1889. This motor (Fig. 6) consisted of a field having laminated pole pieces, and a direct current armature with its brushes short-circuited. On applying an alternating current to such a motor the armature revolves and yields mechanical power.

We can easily see that, at certain positions of the armature, an electro-magnetic repulsion will take place between the field and the short-circuited armature coil, and will thus set the armature in rotation. We may consider each armature coil, when short-circuited by the brushes, as the copper ring which is thrown from the electro-magnet in Elihu Thomson's fundamental experiment.

It is worth while to go a little into detail, and to see how this repulsion is produced. Let us consider the simple copper ring experiment previously described. The magnetic field is an alternating one, and will vary periodically in strength; let us suppose it to follow the sine law. The ring, which forms a closed circuit, will have an E.M.F. induced in it, and this E.M.F. at any moment will be proportional to the *rate of change* of the magnetic flux (Fig. 7). This induced E.M.F. will give rise to an electric current which, however, will lag behind the induced E.M.F., since the ring possesses self-induction.

Now we know that the induced E.M.F. lags 90 deg. behind the magnetic flux, and that the electric current in the ring lags behind the curve representing the induced E.M.F. in the circuit. We may, therefore, represent the magnetic flux, induced E.M.F., and induced current by the curves shown in Fig. 7. Now the force which acts on the ring at any moment is proportional to the product of the current flowing round the ring and magnetic field in which the ring is placed. If we multiply the numerical values of the ordinates (shown in Fig. 7) of the induced current and magnetic field curves, and set up new ordinates to represent these products, we obtain a new curve, representing the repulsive force to which the ring is subjected.

We see from the curve that the ring is alternately repelled and attracted; but the repulsions are much greater than the attractions, and therefore the ring is, on the whole, repelled. It can easily be seen that the repulsion curve depends almost entirely on the lag of the induced current, and therefore on the self-induction of the ring.

I have given this explanation of the ring experiment, because I consider it to illustrate the fundamental theory of the repulsion motor, and from this it can easily be seen how the repulsion motor acts and how the torque is produced.*

To return to the repulsion motor.

Elihu Thomson had no success with his motor on account of poor commutation; this was due to the high frequencies at that time in use. However, during the last few years it has come to the front again on account of the lower frequencies in use (25 ∽ per second), and some excellent results have been obtained. The repulsion motor has an excellent starting torque, and behaves very much like an ordinary D.C. series machine. The modern repulsion motor consists of a laminated iron stator, having the windings distributed in slots (some prefer definite polar projections), just like an induction motor field.

The armature is almost the same as that of a direct current machine with its brushes short-circuited.

The repulsion motor has a very low power-factor at starting; its efficiency is not very high, and commutation is not very good. It is a "transformer" motor; there is no connection between field and armature, and it can therefore be wound for high voltages. Repulsion motors have been made up to 3,000 volts, as the armature can be designed in such a way as to commutate any current.

The simple repulsion motor can be modified in several ways. Repulsion motors may be classified as follows:

1. Simple repulsion motor.
2. Compensated repulsion motor: (*a*) Compensated by having the coil in series with the field; (*b*) Compensated by having the coil short-circuited on itself; (*c*) Compensated by having the coil in series with the armature.
3. Inverted repulsion motor.
4. Inverted compensated repulsion motor: (*a*) Compensated by having the coil in series with the field; (*b*) Compensated by having the coil in series with the armature; (*c*) Compensated by having the coil short-circuited on itself.
5. Series-repulsion motors. (Winter-Eichberg.)

These motors, except the first two and the last, are of no practical importance; most of them are, however, very interesting from a theoretical standpoint, and perhaps some day they may come into practical use.

The inverted repulsion motor has its field short-circuited and the current is supplied to the armature. Fig. 8 will make the different types clear.

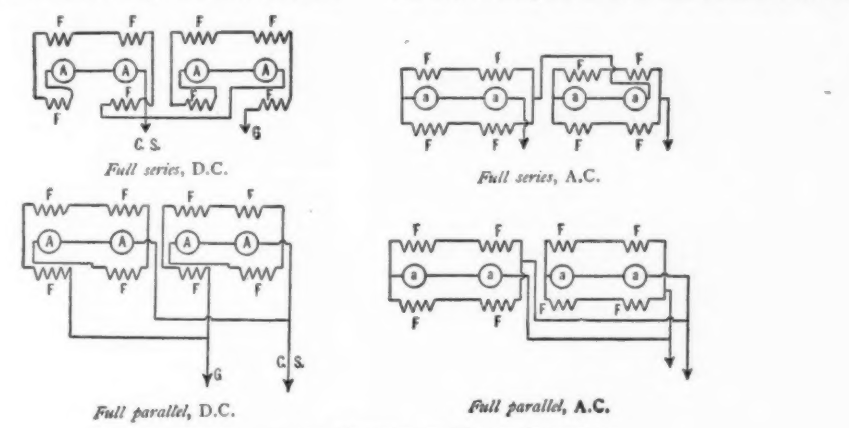


FIG. 11.—TO ILLUSTRATE METHOD OF MOTOR CONTROL.

A, *armature*. F, *field*. C.S., *commutating switch*.

The last one (the series repulsion motor) has been devised by Winter-Eichberg, and is manufactured by the Union Electricitäts Gesellschaft. This firm seems to have obtained some excellent results with it. The great claim of this motor is that its power factor is nearly unity under all conditions of working, and that it is also able to work at high pressures. For a full account of this motor the reader may be referred to an article by F. Eichberg (Electrotechn. Zeitschr. 25, pp. 75-82).

Some excellent results have been obtained with the simple repulsion motor. W. I. Slichter, in a paper read before the Institute of Electrical Engineers in America (see Electrical World and Engineer, 43, pp. 266-267) gives the results which he obtained with two repulsion motors made by the General Electric Company. He carried out some experiments with two 60-horse-power repulsion motors, mounted on a 25-ton car. He came to the conclusion that the repulsion motor is very well adapted for rapid acceleration work, and for freight haulage at moderate speeds, and is more economical than a D.C. series machine.*

Comparison of the Series Motor with the Repulsion Motor.—The repulsion motor being a transformer motor, can be wound for high voltages; it has been built for 3,000 to 4,000 volts.

The series motor, on the other hand, is a low voltage motor (about 200 volts); it can run on either A.C. or D.C. supply, which is a decided advantage.

The repulsion motor can be run at a high voltage without the use of a transformer. On the other hand, it has a very low power factor at starting, causing a large wattless current, while the series motor has a better power factor at starting.

The starting torque of the repulsion motor is a

* D. C. stands for direct current, and A. C. for alternating current.

† See Electrician, April 8, 1904.

* For further information on electro-magnetic repulsions and attractions the reader may be referred to: Phil. Trans. Royal Soc., vol. clxxxiiia., p. 279, Repulsion and Rotation produced by A. C., by Mr. G. T. Walker; Prof. J. A. Fleming, Proc. Royal Institution, xiii., 296, March 6, 1891, and Journal of the Society of Arts, May 14, 1890, and his text-book "A. C. Transformer in Theory and Practice," pp. 307-329; also Elihu Thomson, Electric World, iv., 258, May 28, 1887; xiv., 231, October 5, 1889.

* For information on repulsion motors, see C. P. Steinmetz, Electrical World and Engineer, 43, pp. 268-271, 266-267; M. Latour, Electrotechnische Zeitschrift, 24, pp. 1027-1028; M. Osnos, Electrotechnische Zeitschrift, 25, pp. 1-6, 25-28; M. Latour, Electrotechnische Zeitschrift, 24, pp. 453-454.

little better than that of the series motor, but the running performance of the latter is much better than that of the former. The efficiency of the series motor is a little higher than that of the repulsion motor.

At present it seems that, on the whole, the series motor is the better. It is significant that both Finsi in Italy, and the Westinghouse and General Electric Companies in America, are developing the compensated series motor and use this for traction purposes.

The General Electric Company, who are the holders of Elihu Thomson's repulsion motor patents, abandoned this type of motor, after years of experimenting, in favor of the series motor.

Having considered the various single-phase motors which can be used for traction purposes, we come now to their application to railway work.

Control.—The speed can be controlled by varying the voltage at the motor terminals; this can be done by means of a transformer having several taps, or by means of an induction regulator. Further, we may use plain rheostat, or series parallel control, or we may have taps on the field. With voltage control, however, ideal conditions are obtained, as the waste of power at starting is done away with; the least power is therefore used at starting and at slow speeds. Here an enormous advantage over D.C. working is obtained. Another great advantage is that, with voltage control, we can make up for speed.

It is impossible, at present, to make up for lost time when a train is late. With A.C. working we can raise the voltage a little and, therefore, increase the speed.

A great number of estimates have been made comparing the cost of single-phase with that of D.C. working, using rotary converter sub-stations. In nearly all these cases the cost is less with single-phase working. Look at the enormous advantage of doing away with rotary converters and having high voltage trolleys. All we need are static transformers, which do not (like converters) require skilled attendance.

In urban and suburban work, where many stops are made, the saving of power with voltage control will be considerable. Both the Westinghouse and General Electric companies are equipping roads with A.C. motors, and both companies have all sizes of A.C. series motors up to 200 horse-power on the market. A very successful car has been put in commercial operation between Schenectady and Ballston by the General Electric Company; this is equipped with compensated series motors, and runs both with A.C. and D.C. supply.

As I had something to do with this equipment, I will give a full description of it; this experiment proved to the whole world the success of the single-phase motor for traction work. From Ballston to Schenectady (State of New York) is 15.5 miles, of which 3.9 miles run through the city of Schenectady, which is equipped with 500 volts D.C. trolley.

The Ballston extension had for several months been operated with D.C. equipments, and their operation being continued, necessitated for the A.C. equipment an additional set of trolley wires which would not interfere with the D.C. trolleys.

The D.C. trolley hangs in the middle of the track, while the A.C. trolley is on the side of the track, as shown in Fig. 9. The A.C. trolley is suspended from a catenary, consisting of a ⅜-inch steel cable hung over porcelain insulators fastened to wooden crossarms (Fig. 10). The trolley is clipped to the catenary midway between the poles, giving an excellent mechanical construction and high insulation. The trolley consists of grooved copper wire, and is fed with 2,200 volts A.C. at twenty-five cycles (the standard frequency in America for transmission and power).

The car is equipped with four compensated series motors, each rated at 50 horse-power, a transformer, air compressor, etc., and weighs 30.4 tons without passengers. The motors are of the compensated series type; each consists of an annular laminated iron field with a distributed winding similar to that of an induction motor, together with an armature similar to that of a D.C. motor. These motors are wound for 200 volts A.C. and can be used by changing the field connections (the fields are in two sections) with 250 volts D.C. Two of these motors are permanently connected in series, and are fed either at 400 volts A.C. or 500 volts D.C.

On account of the fact that the car runs for one part of its journey with A.C. and for the other part with D.C., it was necessary to have two trolley poles, one in the middle for D.C. and one at the side for A.C. working. The A.C. trolley base rests on insulators. The high potential trolley wire is taken through brass pipes (which are carefully earthed) to one side of the primary of an 80-kilowatt air-cooled transformer; the other side of the primary is earthed, as the track is used for the return circuit.

Rheostat control is used; part of the resistance is, however, cut out when working A.C., as the self-induction of the rheostats would be too large. The series parallel controller used is the well-known General Electric K-28. A commutating switch is used in connection with the controller; this changes the field connections, the air-compressor connections, cuts out the transformer, changes the resistance, etc., when changing from A.C. to D.C. running.

The commutating switch is interlocked with two main oil switches, one being in the high-tension A.C., and the other in the 500-volt D.C. circuit; this interlocking is so arranged that only one switch can be closed at a time, and the commutating switch can only be thrown over when the oil switches are in the off position. This interlocking arrangement is necessary on account of the fact that there are two trolley poles, and it prevents trouble in case both trolley poles should accidentally be up.

The brakes for the car are operated by air, which is supplied by means of an air-compressor driven by a compensated series motor. The car is geared for about forty-five miles an hour; and on interchanging the field connections it runs at about the same speed whether with A.C. or with D.C. The lights in the car are supplied from a small 7-kilowatt oil-cooled transformer.

As I have already stated, two motors are permanently in series; we may therefore consider the control as that of two motors (Fig. 11).

Naturally the control is effected on the low potential side, so that the motorman does not handle any high voltage. The power factor of the motor is fairly good, about 0.9 at full load.

The efficiency, including gear and friction, is, at full load, about 76 per cent when running A.C., and 80 per cent when running D.C. When running A.C., the commutation of the motors is good, but they spark a little at starting; when running D.C. the commutation is perfect.

The following are some tests which were conducted in order to compare the acceleration of the motors when running A.C. and when running D.C. All speed-time runs on the Ballston line were made over a distance of 1.6 miles on the level at an average speed of 32 miles per hour, or at a schedule speed of 29.5 miles per hour, including 15-second stops.

DIRECT AND ALTERNATING CURRENT RUNS.*

	Direct.	Alternating.
Length of run in miles	1.6	1.6
Weight of car in tons	31.55	31.55
Time, seconds	180	180
Average current in amperes	229	346
Average voltage	606	425
Watts, full speed on level	98	110
Watt-hours per ton mile	86.3	125.5
Average speed (M.P.H.)	32	32
Schedule speed, including 15 sec. stop	29.5	29.5

From these figures we see that when running D.C. the motors are more economical than when running A.C.

The acceleration of the motors when running A.C. is very slow during the first 5 seconds, but after this time they accelerate very rapidly.

Everything on the car is carefully earthed, so as to make accidents due to shocks almost impossible.

The low potential side, as well as the high potential side, are protected by fuses. The high potential fuses are placed on the roof of the car.

The car has been in daily service since August 16, and has given perfect satisfaction. The changing over from D.C. to A.C. running, and *vice versa*, takes only a few seconds.

The successful operation of this car has demonstrated the fitness of the series motor to meet the severe requirements for urban and inter-urban service on either A.C. or D.C. supply. The cars equipped with A.C. series motors are able to run over existing city tracks without in any way interfering with the running of the existing D.C. cars.

The series motor, having demonstrated its fitness for traction work on urban and interurban mixed service, opens up possibilities in converting main line steam roads to electric traction, which would be impossible with the direct current motor and rotary converter combinations, on account of the high first cost and cost of operation.

The commercial development of the A.C. motor is coming at the right moment, as steam railroad managements throughout the world are displaying great activity in electrically equipping portions of their systems now operating at a loss with steam locomotives.

* Electrical World, vol. xliv., p. 322. See also Electrician, vol. liii. p. 826.

THE PHYSICS OF ORE FLOTATION.†

By J. SWINBURNE and G. RUDORF, PH.D., B.Sc.

IT often happens that an invention is made by a process which is in exact accord with the original meaning of the word; that is to say, it is come upon without the inventor necessarily understanding the nature of the underlying phenomena at the time. Scientific people generally arrive on the scene at a later date with explanations which may be right, but are sometimes wrong. We therefore bring forward an explanation for criticism which we think is correct, at present at any rate.

Concentration of sulphide ores by flotation was introduced by Potter in 1901, though concentration by means of oil had been already invented by Elmore. The Elmore process, however, is not a flotation process in the same sense, and therefore does not concern us for the present. Since Potter brought forward the idea of concentration by flotation other inventors have been at work in the same direction; so we will treat the subject rather broadly.

Concentration by flotation is carried out by treating the crushed ore with a suitable solution, such as a strong solution of acid sodium sulphate, at a suitable temperature, which is near the boiling point of water. Part of the ore then rises to the top, and is skimmed off, or otherwise separated, and this forms the concentrate.

The explanation generally given is delightfully simple. It is said that the acid liberates hydrogen sulphide from the sulphides, and the gas then sticks to the particles and carries them up. As the acid does not act on the gangue, which in such cases is largely silicious material, the gangue is not carried up; and thus the separation takes place.

† A paper read before the Faraday Society December 12, 1905.

This theory does not fit the facts. In the first place, the sulphides generally treated are not attacked by the acid solution, so that there is no hydrogen sulphide evolved; or, at most, it is given off in very small quantities, which are out of all proportion to the amount of material floated. The sulphides of zinc, iron, and manganese alone are attacked at all by dilute acids. It cannot, therefore, be the hydrogen sulphide that carries up the particles of sulphide. On the other hand, there is a considerable evolution of gas, but it is carbon dioxide, and carbon dioxide is chiefly given off by the gangue, which generally contains calcite and other carbonates, the carbonates being mostly produced by the weathering of the sulphide particles. According to the theory just given, this action, contrary to what is actually found to be the case, ought to float up either the gangue as a whole, leaving the sulphides, or it should at least float up the carbonates. The next point is that in most cases flotation does not take place at all until the temperature approaches boiling point.

It seems probable that the whole matter is mainly a question of capillarity, or rather of adhesion and surface tension effects, and although other theories have been put forward, we think that ours, besides being very simple, explains the facts best.

Consider first the capillary attraction of the solution, or the adhesion between the solid and the liquid. This phenomenon is a little difficult to examine with surface tension also coming into play. The commonest example is the case of a barometer whose tube has been well boiled, so that there is no air or other gas in the Torricellian vacuum, only mercury vapor. If the barometer is held slanting, so that the mercury runs right up to the top, it may then be put into its vertical position, and the mercury will remain at the top. The liquid mercury is then actually under considerable tension, and, in so far as it is above the barometrical height the mercury is supported by its adhesion to the glass, which it cannot leave. This instance is particularly to the point, because it is often supposed that mercury has no adhesion to glass, which is a mistake. It also shows that mercury has considerable adhesion to itself, or, as it is usually called, cohesion. Liquids have in this sense astonishing tensile strengths—if such a term may be used. Water will stand a pull of 5 megadynes per square centimeter or 5 atmospheres. Berthelot filled a clean tube nearly full of water and sealed it up with a small air bubble. He then heated the water; and under the pressure it dissolved all the air, but on cooling the air did not again separate out; the water occupied the whole space.* It must, therefore, have been under a pull in all directions great enough to increase the volume of the water; and this force was borne by the adhesion of the liquid to the internal surface of the glass, together with its own cohesion. This shows that under certain circumstances the force of adhesion between the water and glass may be very great.

Surface tension depends on the liquid itself. It is, of course concerned with the surface of separation of a liquid and a gas; but we may treat it, to adopt the old idea, as if the surface of the liquid were always in tension like a stretched membrane, except that the tension remains the same whether the surface be increased or diminished. It is measured in dynes per centimeter, just as the tension of the membrane might be measured by making a cut a centimeter long and stitching it up, and measuring the forces on the threads necessary to keep the lips of the cut together.

If a rod is held vertically, partly in a liquid, the adhesion will tend to make the liquid run up the sides of the rod. This movement will be opposed by gravity on the one hand and surface tension on the other. Gravity, of course, tends to keep the surface of the liquid quite level, so that it meets the rod at right angles. Surface tension, considered by itself, tends to keep the surface of the liquid as small as possible, the volume, of course, remaining constant. Thus, if the adhesion, in spite of gravity, pulls the liquid some way up the sides of the rod, the surface of the liquid is increased, and the surface tension, therefore, tends to prevent its rise. If there were no adhesion the surface tension would not allow the surface of the liquid to remain level where it approaches the rod, but would round the corner so as to get the least possible surface. This tendency would be upset by gravity, so that a state of equilibrium would be reached in which the surface was by no means the least for the volume; but any further reduction would be prevented by the force of gravity, which would overcome the surface tension. If the rod, as imagined, has, to begin with, no adhesion for the liquid, the liquid has a curved surface, so that the rod stands in a sort of hole in the liquid, the hole having its top belled like a trumpet. If the rod has a little adhesion the liquid will stick to it up to a level somewhat below the surface, and the liquid will then leave the surface at an angle and begin to turn over from there. As the adhesion is increased the liquid touches the rod higher and higher and leaves the surface at a greater angle, until the surface is level and meets the rod at right angles. If the adhesion is still greater the liquid rises against the rod, the angle changing, until the liquid surface meets the surface of the rod at an acute angle in the new direction. The angle between the surface of the solid and the liquid called the contact angle thus depends on the adhesion, the surface tension, and gravity. Whether it depends at all on the gas in which the whole is immersed we do not know. The surface tension has nothing to do

* Sur les Phénomènes Capillaires. G. van der Mensbrugghe. Rapp. Congrés Int, Phys. 1900. Vol. i.

with the solid, while the adhesion depends both on the solid and on the liquid.

It may be well at this stage to consider briefly the question from a mathematical point of view.

Two distinct capillary forces come into play when any solid is dipped into any liquid. These are, as mentioned above, the adhesion and the cohesion.

1. *Adhesion*, the attraction between the solid and the liquid particles, is measured by the contact angle θ. If $\theta = 0$ deg., i. e., $\cos \theta = 1$, the liquid is said to completely wet the solid. If $\theta = 180$ deg., i. e., $\cos \theta = -1$, the liquid does not wet the solid at all. For values of θ between 0 deg. and 180 deg., i. e., of $\cos \theta$ between $+1$ and -1, there is imperfect wetting.

2. *Cohesion*, the attraction between the liquid particles themselves, is measured by the surface tension T, or, according to Quincke, more correctly by T divided by the specific gravity of the liquid. "Greasy" substances are those for which the cohesion of the liquid is greater than the adhesion of the liquid to the solid. The state of perfect wetting, for which $\theta = 0$, is very difficult to obtain, and even when obtained is difficult to preserve. The angle θ gradually increases on allowing solid and liquid to stand, provided both are in contact with air or some other gas. *In vacuo* it remains more or less constant, depending on the state of perfection of the vacuum. The adhesion, therefore, gets less, and the solid gets "greasier." For this reason it is necessary in determining surface tensions to have a continually formed clean surface, or as Grunmach expresses it, the surface must be *in statu nascendi*. In order to do this Grunmach employed Röntgen's double-funnel method.

Quincke assumed that the solid surface gets coated with a very thin film of gas. For wetted substances this film must be thinner than the sphere of action of the molecular forces (about 0.0005 millimeter) and its thickness affects the value of θ. If the thickness be more than 0.0005 millimeter the substance is getting "greasy," and the degree of "greasiness" increases with time, i. e., as the gas-film gets thicker. This idea seems to have been objected to by Volkmann, but Wüllner showed that his objections were not valid, and later Magie upheld Quincke's work and showed that only in very special cases was $\theta = 0$. This question of the air-film will be discussed more in detail below.

We will now return to the main argument and consider the case of a particle of ore and a gas bell. The surface tension of the liquid tends to make the surface of the liquid as small as possible consistently with its still containing the air. If the particle has no adhesion the surface of the liquid surrounding it must be considered as part of the surface which has surface tension, so that the surface will arrange itself in such a way as to be the least possible to include both the gas and the particle. If the particle is large in proportion to the gas bubble the surface will surround it, the gas filling up any inequalities and helping to allow the surface to take the spherical form. If the particle is small the result will be a gas bell with a particle nearly inside it. Imagine now the particle to be endowed with increasing adhesion. It will first attach itself to the liquid at one or more points, and the angle of contact will become more and more obtuse. As this takes place the particle gets more and more into the liquid and out of the gas bell, until the gas bell is sticking to one side of it. If the adhesion increases more and more the final stage is that the bell has become a sphere which just touches the particle at one point. The bell will then leave the particle. In any intermediate case, such, for instance, as a bell of gas "sticking" to the particle, the adhesion would tend to reduce the surface of the solid that is in contact with the gas, and thus to make the bell more nearly spherical. The surface tension, on the other hand, is tending to make the surface of the liquid, including that in contact with the solid, as small as possible, consistently with its containing the gas.

In order to make particles of ore float up it is, therefore, necessary to get adhering gas bells, and to get these to "stick" the surface tension and adhesion must be properly related. The term "stick" is not, of course, really applicable. The particle does not stick to the air bell. We are accustomed to think of an air bell as if it were something independent of the liquid, floating about in it, forgetting that its attachment to a solid is a question of capillarity and surface phenomena, but for simplicity we may talk of the bell sticking to the solid.

Most constituents of ores have too great adhesion for water or dilute acid to be easily floated. To make it possible to separate them, it is necessary either to diminish the adhesion or to increase the surface tension T of the liquid. If the particles are sufficiently small for bells to raise them, the only conditions necessary are that the bell should be formed, and that the adhesion and surface tension should be rightly proportioned. Surface tension alters with temperature. The surface tension of water at ordinary temperatures is about 75.5 dynes per centimeter, and it falls with rise of temperature, approximately according to the formula $T = T_0 - 0.152t$, until it reaches zero at the critical temperature. As far as surface tension is concerned, therefore, the higher the temperature the less chance of success. But the adhesion is a different question. The adhesion of solids and liquids has been very little studied. It varies very considerably in different substances. Those with least adherence are generally called "greasy." This is because grease has little adhesion with water. Thus such a body as stibnite, which has little adhesion, may well be described as greasy. We are so accustomed to grease as a substance with small adhesion that when we meet others we naturally think them greasy. Thus if a spoon shows little adhesion for water, you know at once that the tablemaid has not rendered it chemically clean, and the small adhesion is due to a thin film of grease. But the small adhesion of stibnite is not due to a film of organic matter. The strange thing is, however, that bodies like stibnite, which have small adhesion for water and thus resemble grease, have apparently a greater adhesion for grease, and can therefore be separated by oil according to Elmore's method. It may be, not that the stibnite and oil have great mutual adhesion, but that the surface tension of the water is the main factor in making the stibnite and oil stick together. There are in this case several factors to consider: the surface tension of the water; the surface tension of the oil; the mutual adhesion of the ore and the water; of the ore and oil, and of the water and oil; so that the question is more complicated.

Returning to the ores, the various sulphides have different adhesions. The gangue, as a rule, has very great adhesion, and cannot be floated. Even such bodies as stibnite, unless very finely ground, have too much adhesion to be floated at ordinary temperatures. The adhesion is altered enormously with change of temperature, however. This is well known in the case of taking out spots of grease from clothes. If the cloth is ironed with blotting paper beneath it, the grease will run from the hot cloth into the cooler blotting paper. In the same way, cloth that seems dry when cooled seems damper when warmed, as the adhesion or capillary attraction is reduced. A thick piece of dry bread when toasted gets quite moist in the center, partly because the water has moved in from the outside, which is hotter than the inside, and partly because the adhesion is less. In the case of ores, many of the sulphides, such as galena, stibnite, and molybdenite, have their adhesion reduced enough to be floated easily near the temperature of boiling water, and though the surface tension is also reduced with increase of temperature, the adhesion is reduced much more quickly. The surface tension becomes zero at the critical temperature; the adhesion probably falls to a very low value at the boiling point.

In order to get concentration by flotation, it is necessary to have an ore whose valuable constituent is some "greasy" sulphide,* such as galena, or at most so automatically attached to the greasy sulphide that it comes off with it. Zinc sulphide is thus easily raised by galena when intimately associated, as in the Broken Hill and some of the Vieille Montagne Company's ores.

It is not enough to have the greasy particles; it is necessary to produce the gas bells and get them against the particles. In practical work the only gas that comes off is carbon dioxide, and this appears to come largely from calcite. But mixing calcite with an ore which has a greasy constituent will not necessarily float it; the gas is apt to come away from the particles of calcite without getting attached to the ore. It seems much more likely that the gas that really effects the flotation is generated by the action of acid on small quantities of carbonates produced by a slight weathering of the ores. It is most likely due to small amounts of carbonate of iron and manganese. These carbonates are also not attacked by dilute acid in the cold.

But there is another consideration. The question of adhesion, and of formation of adherent gas bells is intimately connected with the air-film. Most, if not all, substances condense a volume of air or water, or both, on their surfaces. An extreme case of this is the absorption of hydrogen gas by palladium. No compound is formed here because, according to Roozeboom, the amount of gas absorbed at any particular temperature is *not* constant, but varies with the pressure. Other elements, e. g., vanadium, nickel, and copper, also absorb small quantities of hydrogen, but in no case does the amount of gas absorbed bear any simple atomic ratio to the amount of metal. Thus vanadium absorbs 1.3 per cent of its volume of hydrogen, electrolytic zinc a few hundredths of 1 per cent, copper wire 0.306 volume, ordinary porous nickel absorbs 165 volumes of hydrogen, but loses it again in two to three days, and so on. These solid solutions, occlusions, or condensations, whatever they may be, must be carefully distinguished from the true hydrides, such as those of the alkali metals. The condensation of gases on solid surfaces and the great persistence of the film is especially familiar to workers with high vacua. A glass bulb, for instance, on exhaustion keeps on giving off gas for days. If the bulb is heated as strongly as the glass will bear, the gas comes off much more quickly. A Ruhmkorff discharge also brings it off. If the bulb, while still exhausted, is washed or filled with mercury, it will sweep the gas off the glass.† The electrodes also give off gas on sparking the tubes, and thus gas cannot be got rid of by exhausting the tubes. Very many observers have noticed and described this nuisance. Aluminium is especially obstinate as shown by the experiments of Callendar. The literature is to be found in Kayser's "Handbuch der Spektroskopie," vol. i., pp. 239-243. This air-film seems to be intimately connected with the small adhesion for water. It may be that the air-film is itself the result of adhesion for gas, which is able to condense the gas on the surface. It cannot be any simple action of that sort, however, for time has great influence. Thus the gas comes off the inside of the exhausted globe very slowly, as already mentioned. On the other hand, small metal objects will float on water. Interesting experiments in this direction are recorded by Mayer (Science (II.), 4, p. 298 [1896]). He floated rings of various metals—aluminium, iron, tin, brass, copper, lead, and German silver—made of 1 millimeter diameter wire and 50 millimeters in diameter, on water. The metals, however, must be clean and dry. If, after one of these rings has been sunk in water, it be dried and the experiment repeated, it will be found impossible to float the ring. After leaving it in the air for half an hour or so, it can be again floated. Similarly a heated platinum ring will not float immediately after cooling, but will do so after lying in the air for a short time. This shows that the film takes time to form. Another way of demonstrating the presence of the gaseous envelope is to sift some powdered substance which easily sinks, such as sand or ferrous sulphide, on to the surface of hot water, previously freed from gas by boiling. Bubbles of gas rise from the surface of the solid particles.

Many observers have recorded the floating of perfectly dry sand on water. Among these may be mentioned Simonds (Amer. Geol. 17, 29 [1896], and Science [II.] 11, 510 [1900]); Ladd (Amer. Geol., Nov., 1898); Graham (Am. J. Sc. [III.], 40, 470 [1890]); Nordenskiold (Nature, 61, 278 [1900]); Carus-Wilson and Evans (Ib. p. 318), and perhaps others. Evans also found that pieces of slate 1.5 x 0.75 x 0.1 centimeter float on tap-water, if perfectly dry.

According to Simonds, the floating of the sand depends on the shape of the grains. Ladd notes the same condition, and adds that the pieces must be sharply angular. Felspar and mica will also float under these conditions.

Spring (Bull. Soc. Belg. de Geol. 17, 13 [1903]) has made some experiments on the wetting of sand, and finds that it depends chiefly on the capillary-constant of the liquid and on the fineness of the particles.

However, the substances usually known as gangue are much more easily wetted than the metallic substances. Again, some are much more easily wetted than others. Thus, iron pyrites is easy to wet; that is to say, difficult to float, whereas antimony sulphide is difficult to wet, or easy to float.

A particle which is once wetted will never float, because even if a gas bubble were formed on or round it, it would not carry the solid up, as it falls through. On the other hand, if a particle has still a very thin film on it, but this is insufficient to buoy it up, it is easily conceivable that by generating gas, such as CO_2, upon it, this gas will add itself to this small air-film and eventually raise the particle. Here, again, the temperature seems to be of importance, and this probably explains why a substance like ferrous carbonate, which is not attacked by dilute acid at a low temperature, is better than calcite or copper carbonate which are attacked in the cold.

Nothing is known about the thickness of the air-film, or whether it is the same for all substances; or, as is more likely, variable. But it is very probable that for a given substance the thickness of the film is the same whatever the size of the particle, hence, only small particles can be raised without the addition of some other gas, such as CO_2.

That the air does play an important part is shown in the case of stibnite and molybdenite. They can be concentrated by placing the ore in water nearly boiling. Apparently there is enough air on the surface of the particles to form with the steam a bell consisting of air and steam, which floats the particle. The air-film, or a surface with small adhesion, also gives a bell of gas or of steam a chance of forming. The surface tension makes it impossible for a bell of steam to start, as the bell is under extra pressure due to the surface tension, the pressure of the contained gas varying inversely as the diameter of the bell. Thus a bell of air at ordinary temperatures of 0.01 millimeter diameter has an extra pressure on it of 30,000 dynes per square centimeter, equal to a head of about 30 centimeters of water. The explanation we offer—and it seems sufficient for the Potter process—is, therefore, that all solids have on their surface when dry a thin film of gas, probably air. Some of them, such as sand, quartz, carbonates, easily give up this film in water and become wet; while others, such as most metallic bodies, and especially the sulphides of lead, molybdenum, and antimony, have a smaller tendency to part with the film, and are not easily wetted. These can, therefore, be floated. If the air-film is insufficient to raise the particle, the flotation can be increased by the slow generation of gas on the particle. But if the particle has once lost its air-film, that is to say, got wet, it can never be raised, and no amount of gas generated on it can help matters.

To sum up, we would suggest that the selective flotation is due to the presence of "greasy" sulphides, which have small adhesion, and that a high temperature is necessary to reduce the adhesion enough for the bells of gas to stick. It seems necessary that the gas should be produced at the surface of the particles themselves; and it is, in fact, produced by the decomposition of carbonates due to slight weathering of the ore. If an ore that can be floated is treated with acetic acid to remove the traces of carbonate, it cannot then be floated again. The air-film also plays an important part; and if an ore is thoroughly washed or boiled in water to remove the air-film, it cannot be concentrated with acid. Some ores, such as stibnite and molybdenite, appear to have enough air on their surface to form a mixture of air and steam at a temperature below boiling point, which has enough volume to float the particles. Acid is therefore unnecessary in such cases. Of the various ores and sulphides we have tried in

* This effect of greasiness was well shown by the following experiment. Some ordinary steel filings, which probably had some oil on their surface, were immersed in dilute acid. Hydrogen was evolved round the particles, which were kept dry by the oil, large bubbles rose to the surface and burst, leaving absolutely dry filings on the top of the liquid. Clean, new filings did not show this phenomenon.

† Incandescent Lamp Manufacture. London Electrician, 1887.

dilute acid or acid sulphate of soda, the following are most easily floated, in order of merit:

Molybdenite.
Stibnite.
Galena.
Mixed zinc—lead sulphides, such as the Broken Hill ores.
Copper glance.
Zinc blende.
Iron pyrites.

The last two scarcely float at all. Copper glance only floats if slightly weathered, and then only in very small amounts.

With the Broken Hill ores the ratio of the Zn : Pb in the concentrate differs very little from that in the ore, only the gangue being left behind. Galena is fairly easy to float if finely ground, but owing to its rather high specific gravity very fine pulverization is necessary to float it successfully. Stibnite and molybdenite go quite easily owing to their very greasy nature.

We have made a good many experiments with various ores, but do not think it is necessary to go fully into them here. We have, therefore, only given this short list as an example of the way in which things go.

We also tried some of the gangue obtained from the Broken Hill ores by the Phœnix process due to one of us. This looks like river sand, and consists principally of rhodonites and garnets. Not the slightest flotation was obtained.

It is interesting to note that ground malachite—copper carbonate—floats fairly well in water. It may be remembered that this mineral has a peculiar greasy feeling. Beyond this, we have not found any other carbonates that float.

This list is only roughly correct, however, and it is most probable—in fact, almost certain—that various samples of sulphides differ considerably; and if a slight weathering is necessary to produce the small trace of carbonate needed to give flotation, the "greasiness" in itself is not sufficient to give the separation. It is, in fact, quite impossible to tell beforehand which ores can be separated by flotation.

We have not gone much into the question of merits of the various solutions used for concentration by flotation. Potter originally used dilute acid, preferably sulphuric, of about 2 per cent strength. A saturated saltcake solution is employed by another inventor, Delprat.

We have found that generally the latter solution works rather better than the former, and it has been suggested that this is due to the isohydric influence of the sodium sulphate on the sulphuric acid, thus driving back the dissociation of the latter, so that a saturated solution of saltcake acts as a weaker acid than the dilute sulphuric acid itself. This is, however, not the case for several reasons: (1) The saturated saltcake solution conducts considerably better than the dilute acid. (2) It acts more violently on carbonates and iron than dilute acid. The degree of dissociation is, no doubt, considerably driven back, but as the *total* concentration in one case is so much greater than in the other, the actual concentration of the hydrogen-ions need not be less. In fact, it is only necessary to assume that the saltcake solution is dissociated to about 5 per cent to make the H-concentration the same as that in 2 per cent acid where the dissociation is probably complete, or, at any rate, nearly so. All this is assuming there are such things as ions. With saltcake solution the bubbles get larger than with dilute acid and rise more slowly owing to the greater density and viscosity of the former solution. Certainly a much more stable and compact scum is formed when saltcake solution is used, and this is no doubt due to the viscosity of this solution, but more especially to the *surface viscosity* which is always greater than the ordinary viscosity or internal friction. It is well known that bodies on the surface of a liquid attract one another if *all* be wet or *all* be dry. The former case does not concern us as it only applies when the solid is

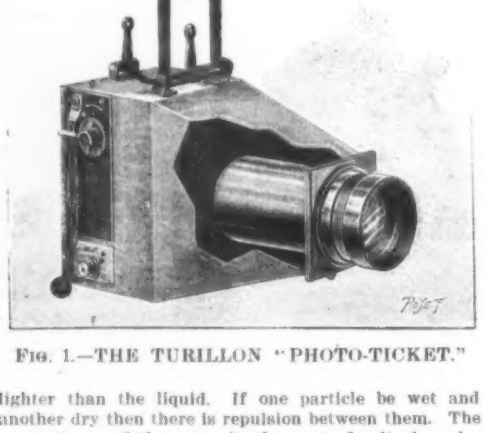


FIG. 1.—THE TURILLON "PHOTO-TICKET."

lighter than the liquid. If one particle be wet and another dry then there is repulsion between them. The compactness of the scum in the case of saltcake solution is, therefore, most likely due to the fact that the particles, on account of the increased surface viscosity as compared with dilute acid, tend to keep drier than with the dilute acid, and, therefore, attract one another, forming a compact scum. It need hardly be pointed out that this apparent attraction is really a surface tension phenomenon again. If particles of dry sand rest on water, each produces a little dent in the surface, and increases its area. The increase of area of the tense surface is least when the particles are all together, making one big dent. This holds good—to a less extent—with greasy particles floating, and with completely wet particles. With wet particles the dents become prominences, but the surface action is otherwise the same.

As regards the actual values of the surface tensions of water, dilute acid and saturated saltcake solution, there is very little difference. Dilute 2 per cent sulphuric acid has the surface tension very little smaller than that of water, and the same can be said of the saltcake solution. The temperature coefficient for water and dilute acid is about the same. It is given

FIG. 2.—THE GUILLON ENLARGING APPARATUS.

by the formula $T_t = T_0 - 0.002t$. For saltcake solution, the coefficient is practically zero. We have tried no other solutions, and are therefore not in a position to give any general explanation for the behavior of various solutions. All we have tried to do is to sketch a rough explanation dealing broadly with the physics of ore flotation.

We are indebted for many facts to Mr. Blount and Prof. Huntington who have both given much attention to the flotation of ores.

A HAND CAMERA CAPABLE OF CONVERSION INTO AN ENLARGING AND PROJECTING APPARATUS.

THE pocket camera is, more than any other, apt to be brought suddenly into requisition for the registering of an interesting subject, and should therefore be capable of being used in all sorts of weather and at any moment. Unfortunately, however, this is an impossibility; and yet, by the use of special objectives and shutters, the limit at which the photographing can be done from the rising to the setting of the sun and afterward in a room lighted by electricity, can be extended. In constructing his "Photo-Ticket" (Fig. 1), M. Turillon, the well-known optician, has therefore naturally thought of modifying the objective. The types usually employed in small apparatus are of short focus capable of giving what is called an automatic focusing, that is to say, starting from 6 to 10 feet. But, on the other hand, as an offset to this advantage of not having to do any focusing, we have an inaccurate perspective, in which the foreground is exaggerated, and, at a distance of from 25 or 30 feet, the figures become microscopic.

M. Turillon, remembering that very large objectives were formerly constructed for the covering of a plate of the size of a carte-de-visite, in order to obtain great luminosity, has constructed for his apparatus a special objective of the Petzval type having a very wide aperture, say of more than three-quarters of an inch, for covering a 1.6 x 2-inch plate. Its focus is 3 inches, and its effective aperture 1.75 inch. In this way is obtained considerable luminosity, as well as relatively large images in which the perspective is not exaggerated. It is true, on the contrary, that it is necessary to have recourse to focusing when no diaphragm is used, for every distance less than 23 feet. Owing to this fact the objective is mounted with slight friction on a tube, and a graduation indicates the focus for distances every three feet apart.

When it is possible, the distances are measured, and for this purpose a small hook is placed beneath the objective in order to permit of attaching a steel tape measure. This may prove especially useful for making a cabinet portrait at a very short distance (less than three feet), in such a way as to have the head alone occupy nearly the entire plate.

In order to obtain as much advantage as possible from the luminosity of the objective there is employed a specially constructed shutter capable of operating at various velocities and of also permitting the making of a time exposure.

The manufacturer has adopted two sizes, one 1.6 x 2 inches and the other 0.75 x 1 inch. With this latter size, portraits taken from a very short distance have the appearance of a postage-stamp.

The body of the apparatus is of cast aluminium; the direct vision finder consists of a frame and sight-hole; and the plate-holders, which are of metal, are so arranged that the entire surface of the plate shall be utilized—a great advantage seeing that it is of such small dimensions. The use of small apparatus naturally suggests the idea of making enlargements, and sometimes a special arrangement is the addition that the manufacturer has provided for this purpose. In most cases it is an easily employed, but somewhat cumbersome rigid cone. M. Guillon, who has made a specialty of the manufacture of these kinds of enlarging devices, has recognized the fact that many amateurs do not always have a place for housing such apparatus and are obliged to give up the idea of carrying them to the country where, nevertheless, time might be found to utilize them. It is for this reason that he has constructed a dismountable apparatus which, after being folded, is packed in a flat box that takes up but little space (Fig. 2). The principal part, *B*, which is in the form of a truncated cone, folds in the center of each of the short sides. The part, *A*, placed above, is provided with a hinge on each side. In order to keep them open when the apparatus is mounted, these parts are set into wooden frames, one of which, *C*, at the lower part, serves as a frame for the enlarging paper, while the other, *M*, at the upper part of the box, *A*, carries the objective and the shutter, *D*. Above are placed the negative and a plate of ground glass, *E*. After all the parts have been put together, they form a strong apparatus which is easily operated in all directions upon securing the springs, *T R*, on each side.

The method of using is the same as that described with regard to non-dismountable apparatus. It is very simple and any explanation concerning it would be superfluous. We shall simply say that although this kind of apparatus necessitates the use of daylight when it is a question of enlarging negatives of quite a wide surface, it is possible with small ones to employ the magnesium light, especially when the magnesium is burned at quite a distance from the ground glass and displaced continually during the combustion. Under such circumstances the negative will be illuminated with sufficient uniformity to prevent the image from being exposed more at one place than at another.

As amateurs often wish to exhibit their work in the form of projections to a party of friends, MM. Radiguet and Massiot have devised to render the projection as easy as possible by arranging a small apparatus that shall always be ready for immediate operation. It suffices, in fact, to open a 5 x 16-inch box and turn back its cover in order to make the apparatus ready for use (Fig. 3). As for the lighting, that is effected by simply connecting the apparatus with the socket of an incandescent lamp by means of a flexible wire. The lantern consists of a cylindrical body, *P*, upon which are mounted the objective, the lantern slide holder and the condenser. Into the rear is set a Nernst lamp which, with a current of 110 volts and a consumption of about one ampere, gives sufficient light for the projection upon the screen of a 5.25-foot image with a 1.5 x 2-inch negative. For such dimensions, the lantern has been hitherto employed with the Richard "Verascope," and is now widely used with many other apparatus, such as the Gaumont "Stereo-block Notes." But MM. Radiguet and Massiot are also going to establish the same type for the 2.25 x 2.25-inch dimensions of the Leroy "Stereocycle," of the Joux "Stereo-pochette" and other apparatus. Above such size, it is preferable to use the ordinary lantern, because the necessary dimensions of the condenser and lamp do not permit of giving the apparatus the neat and compact form that the manufacturers have succeeded in giving the one under consideration.—Translated from La Nature for the SCIENTIFIC AMERICAN SUPPLEMENT.

HOW BRILLIANT METALLIC SURFACES ARE FORMED ON POTTERY.

IN a paper presented to the Académie des Sciences, L. Franchet describes his researches upon the formation of brilliant metallic surfaces upon pottery. In view of the interest of these processes, we give the details of operating in full. The metallic deposits, often of an iris luster, which are obtained on the surface of

FIG. 3.—THE RADIGUET AND MASSIOT PORTABLE PROJECTING LANTERN.

pottery under the influence of reducing gases, seem to be of Arab origin. In 1831 Laurent, in analyzing some ancient ceramics thus decorated, showed that the enamel did not contain gold. In 1844 Brongniard, who made some trials to obtain the metallic effects, found some interesting results, but these were incomplete. The author took up the question in 1896, but instead of using Brongniard's method of projecting oxide of copper in the muffle, or else of applying a metallic composition upon a ceramic piece already enameled and baked, he incorporated salts of silver, copper,

and bismuth in a paste which he composed so that the vitrifying point corresponds to 970 deg. C., which is the baking point for Vallauris faïence. The paste which he calls A is thus composed: Quartz 12, pegmatite 10.5, Eyzies kaolin 2, Decize sand 20, minium 30, borax 19.2, boric acid 2, carbonate of potash 2, salt 1.8. The mass is pulverized, melted, run in water and ground up. He then made up the following three typical formulæ: No. 1. Paste A, preceding, 100 parts, kaolin 10 parts, carbonate of silver 2 parts. No. 2. Paste A 100, kaolin 10, zinc oxide 1, tin protoxide 1, carbonate of silver 0.5, oxide of copper 3. No. 3. Paste A 100, kaolin 10, sub-nitrate of bismuth 4, carbonate of silver 2, carbonate of copper 1. These pastes, prepared by simple grinding, are applied on the faïence like ordinary pastes, a small amount of gum being added, diluted in water, to facilitate the use. If they are judged too fusible, we increase the amount of kaolin, which is lowered in the contrary case. Like pastes can be made for earthenware or porcelain.

The baking is carried out by the usual methods in an ordinary muffle whose chimney is provided with a tight-closing register. When the right heat has been reached, the fire is removed from the furnace and we cool down to low red heat, then proceed to the reduction of the paste. For this, the register is completely closed. For the reduction of the metallic paste we use three methods, first, the production of an intense smoke in the muffle of reducing gases given off by combustion of saccharose or glucoses. As to the first process, ever since the fourteenth century the Arabs (and perhaps the Persians before this) obtained metallic luster effects by producing the smoke by burning dry plants. Any kind of smoke will do, and we use here wood, oil, resin, coal, tar, and the results are the same. When the register is closed, the tar, for instance, is thrown in small portions in the furnace which is still hot enough to give a thick smoke. This goes into the envelope of the muffle and as it cannot go out by the chimney it penetrates into the muffle itself by the top evaporation pipe, then escapes by the front, which is left open. After one hour or more, if the smoking has been done regularly, the reduction of the paste is effected. After five hours the luster becomes too dark. As to the second method, the use of gas as a reducing agent is not new, but owing to the exactness of the process it enables us to observe the different phases of the reduction of silver. The disposition is the same as before, except that the gas penetrates into the muffle by iron or copper tubes which lead through the sides and which are put in at the moment of operating. All the air inlets without exception are tightly closed so as to avoid either an explosion or combustion of the gas. The tubes are disposed by 8 or 10 for a total supply of 3 cubic yards per hour, the muffle having 0.5 cubic yard capacity. The reduction takes place in ten minutes and we find that according to the time of the operation (which should not exceed thirty minutes) the tone of the reduced silver passes by five modifications. First phase, brass metallic tone; second phase, gold tone; third, yellow and but slightly metallic tone; fourth, blackish brown tone; fifth, non-metallic tone. In the second phase the gold tone is especially remarkable, although the silver salts which are used contain neither gold nor copper. In the third to fifth phases, the metallic luster is absent, but it can be revivified by operating a new baking and a new reduction.

The metallic luster is developed also, but more irregularly, under the influence of the gases produced by the combustion of saccharine matter. This process, which is a very simple one, is but slightly energetic. The saccharine matter is introduced into the muffle by a small opening arranged to that effect, and we take care as before to carefully close all the openings.

We have dwelt upon the curious effects which are obtained with the use of silver. Copper always keeps the tone which belongs to it, but the addition of bismuth, as in formula No. 3, gives a remarkable blue color, which is generally a pearly luster. By combining formulæ Nos. 1 and 3 we can obtain a very brilliant metallic green, which is a combination of the yellow and blue.

A MINIATURE CALORIC ENGINE.

The hot air engine is not a very recent invention. A number of engines of this class, of different sizes, were devised and used in the early part of the last century, and in the latter part of the previous century there were in existence engines constructed to be operated by the expansion of air.

Nothing in the way of a motor, aside from a windmill or waterwheel, can be more simple than this, and it is a pity that it is not capable of more general application. Motors of this kind have been used to some extent for driving light machinery, and they have been largely employed in pumping water.

Quite recently caloric engines have been made in the form of a toy, as illustrated in the larger of our engravings. In the motor here shown, the air contained in the expansion cylinder is alternately heated and cooled, and no fresh air is introduced. This action is so rapid in a small engine that the crank shaft can make 600 or 700 revolutions a minute. By examining the sectional views (2, 3, and 4) a good idea of the construction and operation of the motor may be obtained. In brief, the larger and longer of the two cylinders (the expansion cylinder) contains a long hollow piston called the "transfer piston," which fits the cylinder very loosely. To this piston is attached a rod extending through a close fitting sleeve in the top of the cylinder, the piston rod being provided with a connecting rod fitted to the crank at the middle of the shaft. The upper part of the expansion cylinder is furnished with a wide flange forming a cap which fits over the sheet iron fire box, and to the top of the expansion cylinder are secured the standards in which is journaled the crank shaft.

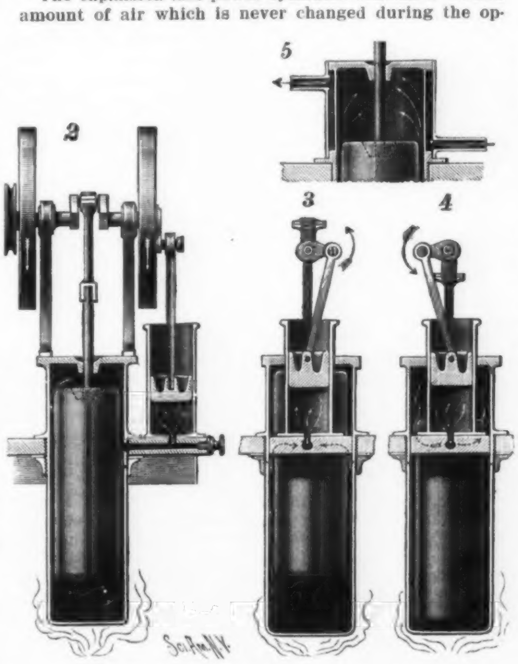
To the flange is attached the power cylinder, which is shorter and smaller in diameter than the expansion cylinder. This cylinder is provided with a piston to which is pivotally connected the lower end of a con-

SMALL CALORIC ENGINE.

necting rod, the upper end of which receives a crank pin projecting from one of the fly wheels at right angles to the transfer piston crank. A hole bored in the flange connects the expansion cylinder and the bottom of the power cylinder, as shown in Fig. 2, and the outer end of the hole is stopped by screw plug which can be removed for cleaning the hole, should it become stopped by oil or otherwise.

An alcohol lamp is provided for heating the expansion cylinder, it being placed in position to heat the lower end of the cylinder, as shown in the larger view. The top of the lamp is provided with a hemispherical cavity, at the bottom of which is the aperture for filling. The stopper consists of a marble dropped into the hemispherical cavity and serving the double purpose of stopper and safety valve.

The expansion and power cylinders contain a certain amount of air which is never changed during the op-



SECTIONAL VIEWS OF SMALL CALORIC ENGINE.

eration of the engine, except by expansion and contraction. Heat having been applied to the lower end of the expansion cylinder, the engine is started by giving the crank shaft one or two turns in the direction indicated by the arrows on the rims of the fly wheels. The air at the top of the expansion cylinder is transferred to the lower end of the cylinder by the transfer piston as it rises; at the same time the power piston descends, and by this time the air is heated in the lower part of the expansion cylinder and begins to expand. The power piston is in position to be pushed up by the air pressure. As the power piston reaches the upper end of its stroke, the transfer piston descends and transfers the heated air to the upper end of the expansion cylinder, where it is cooled, thus reducing the pressure and allowing the power piston to descend again. This operation is repeated at every stroke. It is almost impossible to believe that the air can be heated and cooled so rapidly.

The efficiency of the motor can be increased by surrounding the upper portion of the expansion cylinder by a water jacket provided with a water supply pipe at the bottom and a discharge pipe at the top, as shown in Fig. 5, and keeping a continual flow of cool water through the jacket. When the motor is used for pumping, the water is forced through the jacket.

This little motor is only a toy, but it very completely illustrates the principle of one of the most successful hot air engines ever devised. If the reader is mechanically inclined, he may make a motor on this plan on a much larger scale, and use it for driving machinery. There can be no doubt about its successful construction or operation, if it is made airtight and the bearings and friction surfaces are made to run free. The proportions may be about the same as shown in the cut.

The dimensions of the motor from which the views were made are as follows:

	Inches.
Length of expansion cylinder	4 3/4
Internal diameter of expansion cylinder	1 5/16
Length of transfer piston	2 13/16
Diameter of the transfer piston	1 1/4
Length of power cylinder	1 3/4
Diameter of power cylinder	21/32
Length of the cranks	7/16
Diameter of fly wheels	3
Height of firebox from base	5 1/2

THE FIXATION OF ATMOSPHERIC NITROGEN.*

When the scientist characterizes the whole subject of the fixation of nitrogen as of the greatest interest to mankind, he thinks of the biological and physiological sides of the problem. Four-fifths of the air we breathe consist of nitrogen; but we exhale that nitrogen again as useless, and the French and German names for the element indicate that it does not sustain life. Yet we know that this same sluggish element forms an essential constituent of the protein substances, which, in the wider sense, build up the cells of all living organisms. When that fact was once understood, the question of the circulation of nitrogen in the household of nature became of the highest importance. The plant derives the nitrogen it needs from compounds of the nitrate or ammonia types. Some plants appear to be able directly to assimilate atmospheric nitrogen with the aid of certain bacteria, and in recent years more or less successful experiments have been made artificially to propagate those bacteria and to foster their symbiosis (co-existence) with leguminous plants. Most plants, however, depend on the nitrogen compounds they find in the air and in the soil, and modern agriculture does its best to fertilize poor soils by means of nitrogenous manures.

We have two chief sources of nitrogen compounds, neither inexhaustible. The one source lies in our coal-beds and gas works. Ammonia forms one of the most valuable by-products of gas distillation, and this source will remain available until our coal-stores give out. The natural occurrences of nitrate of soda form the other source. There are nitrate beds in Spain, east of the Caucasus, and elsewhere; but practically all our soda-saltpeter comes from the Pacific coast of South America, from the rainless Atacama and Antofagasta districts, which, up to 1879, belonged partly to Bolivia and partly to Chili, and which are now all Chilian territory. The exports of Chili saltpeter began about 1830; by 1875 they totaled 200,000 tons annually, and at the present time the annual exports have reached 1½ million tons. If the consumption should continue to increase at the same very steady rate, the saltpeter stores will barely last another twenty years, according to Vergara's estimate. Broadly speaking, it may be said that four-fifths of the Chili saltpeter is utilized in agriculture, while the remaining fifth is claimed by the chemical industry for the manufacture of nitric acid, nitrates, explosives, and various compounds.

Of late chemists have been eagerly looking for means of again utilizing the only inexhaustible nitrogen stores—those of our atmosphere. Henry Cavendish, in 1781, and both Cavendish and Priestley showed the way in 1786. Electric sparks were seen to oxidize part of the atmospheric nitrogen to acid compounds. The fact was re-observed by Bunsen in 1857, and chemists remembered it when chemical laboratories could be joined to electricity-supply stations. But the yields of nitrogen oxides were always very poor, and it became more and more clear that the reactions were of an exceedingly complicated character. Rayleigh made, in 1897, some very interesting observations on these reactions in the course of his researches, which resulted in the discovery of argon. By 1902 an electrothermic technical nitric acid process seemed to have been worked out in Pittsburg. It did not prove a commercial success, however; and when another new process was described at one of the International Congresses held in St. Louis in 1904, experts suspended judgment. But there is no doubt that the saltpeter works at Notodden, in Norway, make a good calcium nitrate, and that the practical and theoretical problems have considerably advanced

* Engineering.

during the last few years. We will first discuss the general theory in the light of the most recent knowledge.

When electric sparks and silent discharges of high-tension currents pass through the air, the oxygen is ozonized and the nitrogen oxidized to various compounds, NO, NO_2, N_2O_4, N_2O. The chief product of sparking devices is NO, which can further be transformed into nitric acid; the lower oxide N_2O (the laughing gas of the dentists) seems to result from the re-decomposition of NO. That N_2O_3 is also formed has only been asserted by Berthelot. In any case only a few per cent of the nitrogen under treatment are oxidized, and the separation of the oxides from the excess of air is not the least difficult part of the problem. The oxygen and ozone can afterward be absorbed by pyrogallol, which would also take up the N_2O; the other nitrogen oxides are absorbed by water, caustic alkali, or sulphuric acid. According to Lunge and Berl, sulphuric acid is the best of these laboratory absorbents; technically its use would, of course, be inconvenient. Scheuer observed that some white vapors pass through all the absorbents he tried, and he suggests the formation of unknown nitrogen compounds; one might also think of compounds of argon, which, it will be remembered, owes its name to its great sluggishness. Most of the products of sparking can be liquefied, and this method may prove of some utility; but Stavenhagen could not condense all his products by means of liquid air, and the NO, the chief oxide aimed at, has the low critical temperature of —93.5 deg. Cent. The N_2O can more easily be condensed; it is an indifferent gas, however, which cannot directly be higher oxidized to nitric acid, and must hence be regarded as an undesirable by-product of these reactions.

The nitric oxide (NO) combines with the oxygen of the atmosphere to the dioxide NO_2, which is characterized by brown, most irritant, and poisonous vapors. In their concentrated condition these vapors are, at high temperature, almost black; at lower temperatures the color becomes lighter, while the density of the gas increases. This is due to a polymerization, the compound NO_2 passing into N_2O_4. In the presence of water NO_2 yields, according to the proportions of the constituents, nitric acid (HNO_3), nitrous acid (HNO_2), and also nitric oxide (NO). For most purposes the nitrate and nitric acid should be free of nitrite and nitrous acid, and mixtures of the two salts or acids are hence not of high value.

The technical electrothermic nitric acid process may now be said to consist of several stages: the oxidation of the nitrogen by the spark or flame, which is effected in a kind of furnace; the reaction between the NO with oxygen to form NO_2, effected in reaction chambers; the absorption of the oxides by water or some caustic lye to form nitrates and nitrites or the free acids.

The oxidation of the nitrogen requires a high temperature, which can be produced by electrical or by other means. The most suitable temperatures of the small arcs and flames used for these reactions have been estimated from 1,600 deg. to 3,000 deg. C. They depend upon the length of the arcs and other conditions. All the estimates are uncertain, moreover; and Nernst has pointed out why this must be so. We determine the composition of the resulting gas mixture after it has cooled down; but since the cooling cannot be effected instantaneously, too little will, as a rule, be found of the compound which was formed at the highest temperature. Nernst himself experimented with his glow-lamps and with his tubular platinum and iridium furnaces; the air was simply heated and not exposed to electric discharges. The resulting NO is redecomposed if kept too long in the flame, and has hence to be quickly removed. The investigator has therefore to determine at what temperature and what rate of air-feed an equilibrium can be maintained insuring the maximum yield of NO. Nernst found that at 1,811 deg. C. the equilibrium constant was 0.37—i. e., 0.37 per cent. of the nitrogen supplied was oxidized, under the particular experimental conditions, when 1 liter of air passed through the tube in 20 minutes; at 2,033 deg. the constant was 0.64; at 2,195 deg., 0.97; and at 3,200 deg., 5. These data agree with the calculated theoretical values, except that the 5 is too high; it should be 4.4. We gain the impression that the reaction is essentially thermal, and not electrical; and, in fact, the electric discharges and the ultra-violet and other radiations which accompany the spark and glow discharge only favor the formation of ozone, which is not a useful by-product, as is frequently assumed. Ozone being a powerful oxidizing agent, should, it has been supposed, support the further oxidation of the nitrogen. But the ozone, formed as an endothermic product at the highest temperatures, is destroyed again in the cooler portions of the vessel (Clement); and Stavenhagen and Lepel have demonstrated that it does not contribute to the completion of the oxidation processes.

Electric and sparking devices are—or should therefore be—applied mainly because they afford convenient means of heating currents of air to high temperatures, while allowing of an easy control of the circulation. Lovejoy and C. S. Bradley, whose successful technical experiments of the first years of this century have given such a strong impulse to a scientific investigation of the problem, seem to have partly been guided by different considerations. They recommended direct, not alternating, currents of very high tension, 10,000 volts, broken up into a great many small arcs or sparks of low intensity with the aid of a rotating multiple circuit-breaker, consisting of a drum of twenty-three spoke wheels, on a common vertical shaft, each wheel provided with six spokes; each revolution of the wheel gave 623 sparks of 0.005 ampere, and with 500 revolutions per minute they obtained more than 400,000 sparks per minute. Choking coils were inserted in the separate circuits, and the drum placed within an iron cylinder, the air feed being regulated so that the temperature of the air current inside did not exceed 80 deg. C. The Atmospheric Products Company, of Niagara Falls, took the matter up, and passed the gas mixture afterward through reaction chambers and through coke towers, in which water and caustic soda were used as absorbents. It was stated that 1 pound of nitric acid could be obtained at the expenditure of seven electric horse-power-hours. But the apparatus appears to have proved too costly, and the yields, mixtures of nitrate and nitrite, too low, and of too small value; for, beyond improvements of the electric appliances, nothing has been published since 1902, and the plant has remained in the experimental stage. The same may be said of the work which Kowalski and Moscicki have carried on during about the same time in Fribourg, in Switzerland. These investigators applied triphase currents of 50,000 volts maximum, and special interrupters with choking coils and condensers, built up of silvered glass tubes immersed in oil.

The great advantage of rotating over stationary circuit-breakers is that with the former we are pretty sure to get the numerous desired sparks of small volume instead of big discharges at a few accidentally-favored contacts. This was recognized by F. von Lepel, who again took up his former work in this field in consequence of the American publications. He uses fine porcelain tubes to ascertain the gas composition at different distances from the electrodes, and point anodes of copper or zinc, and cathode disks of platinum or carbon, both rotated by simple means in the same or opposite directions. He further wets the electrodes with sprays of certain solutions, and gives the spark the shape of a conical flame. To have demonstrated that the electric flame is more suitable for these oxidations than the spark is the merit of W. Muthmann and H. Hofer. High-tension discharges take in air the shape of flames in which, analogous to the candle-flame, three parts may be distinguished: (*a*) A luminous blue core; (*b*) a bluish-green mantle around and principally above it; (*c*) an outer sharp-pointed mantle of brownish color. The electrical discharge takes place mainly in the hottest zone *a*; non-conductors held in *b* and *c* do not affect the pressure and current noticeably, nor does the material of the electrodes make any essential difference. In pure nitrogen and in hydrogen the flame consists of one zone only. Burning in air, the flame produces NO; a flame burning in an NO atmosphere decomposes the NO again into N and O. According to Muthmann and Hofer, the NO production occurs particularly in zone *b*, and Lepel and Stavenhagen also recommend short flames of pale greenish color, not of bluish tints. According to Brode, who separated the zones, cooled the flames, and gained up to 8 volume per cent of NO (which indicates a temperature of 3,700 deg. C.), NO, zone *a* is most efficient. Muthmann and Hofer increased their yields by applying mixtures of nitrogen and oxygen, rich in oxygen, and by condensing these gases; but flames cannot easily be maintained in condensed gases.

A real success has been achieved by Kristian Birkeland and S. Eyde with the aid of flame electrodes of the magnetic blow-pipe type. A powerful magnetic field flattens out an arc discharge; with alternating currents a complete flame disk results, with direct currents a half disk. What really happens is, that each little arc is deflected and caused to travel away from the electrodes, until it breaks off; a new arc is at once formed, and thus the disk consists of a series of little arcs in motion which are automatically extinguished. With alternating currents the arcs travel alternately to the right and left, thus producing a flame disk. Mr. Birkeland is professor of physics at the University of Christiania. He was chief of the Norwegian expedition sent to Spitzbergen in 1899 and 1900, and again in 1902, in order to study auroral lights; and his beautiful experiments on the deflection of cathode rays in magnetic fields may have suggested to him the use of these flame disks. Their action is so strong that, in lecturing in November last, on the novel process in the new chemical institute of the Technical High School at Charlottenburg, Prof. Otto N. Witt had to perform the experiment in a cupboard, lest the atmosphere of the theater should be poisoned. Mr. S. Eyde is an engineer to whom much credit is due for mechanical improvements.

The first communication on the process was made by S. Edstrom at St. Louis in 1904. The experimental furnace then in use worked at Ankerlökken, near Christiania, with arcs consuming up to 200 kilowatts per pair of electrodes, fed with alternating currents of 5,000 volts and 50 cycles. The three furnaces now in operation at Notodden absorb 500 kilowatts each. The furnaces form cylindrical boxes, standing on their edge, or, rather, suspended between two vertical uprights, to the ends of which the coils of the electromagnets are attached. The poles lie in the horizontal axis of the cylinder, and the two perpendicular arc electrodes are at right angles to them. The flame disk of each furnace has a diameter of more than 2 meters. The air enters through ports on both sides of the disk, and is drawn off below, having passed right through the plane of the flame.

The electrodes are hollow copper rods, rounded off and closed at the ends; water circulates in them, and as the striking points of the arc are constantly being shifted by the magnetic deflection, the wear of the electrodes is inconsiderable. Electrodes have, in fact, been kept in uninterrupted use for hundreds of hours. The patent specifications mention various devices for mechanical interruption of the current by imparting a reciprocating motion to either or both the electrodes, or by inserting tuning-forks, etc., in the circuits. It does not appear, however, that these devices are actually applied.

The air leaving the furnace contains not more than 2 per cent of NO, and passes first into the reaction or oxidation chambers, in which the gas current is checked in order to cool and to oxidize the NO to NO_2. That these reaction chambers must have ample dimensions, and that sufficient time must be allowed, is clear from Lepel's researches. The gas is then conducted to eight absorption towers, built up of granite and charged with quartz, in which the gas meets water. The dilute acid flowing off below is again raised, and made to trickle down once more, until the contents of HNO_3 have risen to 50 per cent. Two more towers, irrigated with milk of lime, and further, a dry lime chamber, are added to absorb the last traces of acid. The obtained nitric acid is neutralized with limestone, and the calcium nitrate is evaporated and fused with the waste heat of the reaction chambers, and run into iron cases. Among the improvements now under trial is one according to which the NO_2 gas is directly passed through the evaporation pans. Any perfection permitting of a more direct method of binding the very dilute gas mixture would, of course, be of the greatest importance, and the technical problems concern the chemist and engineer more than the electrician.

The average yield is now, at Notodden, from 500 to 600 kilogrammes of HNO_3 per kilowatt-year. This statement by the firm is fully borne out by independent tests carried out by several methods, which Prof. Witt conducted on various occasions, and which repeatedly yielded a considerably higher efficiency. There is abundance of available water power. The Tinfos, near by, which is now utilized, can spare 20,000 horse-power; the Svälgfos, three miles off, could give 30,000 horse-power; the Rjukanfos, further off, 300,000 horse-power; and it is calculated that the horse-power could be obtained at the exceptionally low rate of 12s. per year. Under these circumstances the good calcium nitrate produced at Notodden could certainly compete with the Chili saltpeter. The furnaces have converted 700 kilowatts for long periods without showing signs of wear. In addition to the works at Notodden, Birkeland and Eyde have an experimental installation at Vasmoen. The calcium nitrate is not the best paying nitrate; but it gives a good fertilizer, especially in the novel modification of a basic salt, which forms a dry, non-hygroscopic powder.

The whole process is, moreover, in so early a stage that further substantial improvements may confidently be looked for. The thermal reactions are very complex, and they need further study. But the foundation has been well laid. The gases should not be dry. At very high temperatures nitrogen decomposes water gas, and 1.5 per cent of NO are formed at 3,000 deg. C., according to Tower. The presence of water promises better yields, and more HNO_3 than HNO_2. Lepel increases his yields by spraying solutions of salts or acids into his furnace, one drop every eight seconds or so, and he obtains better results with mixtures of two compounds—e. g., sulphuric acid and copper sulphate—than with either of those alone; for electrodes of carbon or ferro-titanium a spray of titanium chloride answers best. A great deal depends, further, upon the direction in which the air enters and upon the shape and size of the furnace. Any convection currents and eddies which reintroduce the air already treated into the flame are injurious. Stavenhagen suggested the avoidance of such eddies by using long tubular vessels; but as the flames are never quite symmetrical, this arrangement is not to be recommended. Scheuer has studied, both with induction apparatus and with high-tension transformers, the influence of the watt supply, of electrode gaps, shape of the vessels, direction of the air currents (inclined, upward, downward), their speed, the shape and materials of electrodes, and other conditions, and has also experimented with electrodes of the horn lightning conductor type, forcing the flame to travel upward or downward. The results of his long-continued researches are summarized in many tables and curves, whose perusal is to be recommended. He confirms most of the conclusions which we have stated. The electrode material—copper, nickel, iron, platinum, carbon, etc.—seems to be of little importance, the current intensity and tension and the frequency are important factors; the flame surfaces should be large, and their color greenish, rather than bluish.

There are other electrical or electrothermal ways of binding the atmospheric nitrogen. One only of these has acquired a certain practical importance. It is the fixation of nitrogen by calcium carbide—which is made in the furnace itself from the ordinary materials, lime and coal—under formation of cyanamid ($CaCN_2$), which is directly used as a fertilizer under the name of "Kalkstickstoff," and which, moreover, can easily be converted into dicyandiamid and sodium cyanide. This process has been worked out by Caro and A. Frank, in conjunction with other gentlemen on the staff of Messrs. Siemens and Halske. But the Kalkstickstoff has not everywhere given satisfaction—not, e. g., at the Rothamsted Experimental Station, in Hertfordshire, under A. D. Hall; and in any case the atmospheric nitrogen introduced into the carbide furnace has first to be separated from the oxygen. The other processes of H. Pauling, E. G. Werner, J. Mitchel and D. Parks, and others for the electrothermic treatment of gases are only known by patent specifications. An electrolysis of fused sodium nitrate for the preparation of nitric acid and sodium was practised a few years ago in Philadelphia; it was not successful, however.

As we have had inquiries concerning this subject, and particularly concerning the Birkeland-Eyde process, we add a few literature references. The description by S. Edström will be found in the Transactions of the American Electro-Chemical Society, vol. vi., page 17, 1904; the instructive lecture by Prof. Otto N. Witt on the process as now worked at Notodden, and on the whole problem, was published in the Chemische Industrie, Berlin, of December 1, 1905. The Birkeland-Eyde patents are: English patent, 1903, No. 20,079; French, No. 335,692; United States, Nos. 772,862 and 775,125; German (applied for), B 34,093; Norwegian patents, 13,240 and 13,280. The British patents of Lovejoy and Bradley are: 1901, No. 8230; 1902, No. 14,780. Most of the scientific researches to which we have referred have appeared in the Berichte der Deutschen Chemischen Gesellschaft, abbreviated "Ber.;" these are: F. v. Lepel, Ber., 1903, page 1,251; 1904, page 712; 1905, page 2,524. Muthmann and Hofer, Ber., 1903, page 438; A. Stavenhagen, Ber., 1905, page 2,171. O. F. Tower, "Action of Nitrogen on Steam," Ber., 1905, page 2,945. We have further to mention: W. Nernst, Nachrichten Ges. Wissensch., Göttingen, 1904, page 261; J. K. Clement, "Ozone Formation," Annal. der Physik, vol. xiv., page 334; E. Rasche, Dingler's Journal, vol. cclxii., page 318 (all three on the thermal equilibrium); O. Scheuer, Zeitschrift für Elektrochemie, September 1, 1905, page 565; and J. Brode, ibid, page 752, October 27, 1905.

THE CHANGES IN THE NERVE AND MUSCLE WHICH SEEM TO UNDERLIE THE ELECTROTONIC EFFECTS OF THE GALVANIC CURRENT.*

By Prof. JACQUES LOEB.

WHEN we send a constant current through a nerve, the irritability of the latter is increased in the region near the cathode and decreased at the anode. While this so-called electrotonic effect lasts as long as the current goes through the nerve, there is another effect of the current, viz., a contraction which occurs only at the moment the current is made or broken (or its intensity suddenly changed). Since the impulse for the make contraction starts from the cathode and that for the break contraction from the anode it is generally assumed that the making of catelectrotonus and the disappearance of the anelectrotonic condition cause the contractions of the muscle at the making or breaking of the current.

Through the work of Faraday and Arrhenius the fact has been definitely established that in liquid conductors the current can only be carried by ions and that these ions exist already in the liquid conductor before the current goes through. Since tissues can only act as liquid conductors, a current cannot pass through a nerve or a muscle except through the motion of the ions.

Since the effect of a current only occurs at the electrodes (or wherever the free passage of ions is completely or partly blocked), an explanation for the effects of a galvanic current upon nerve or muscle must look for the possible phenomena at the electrodes (or where the progress of the motion of ions is blocked). In a liquid conductor two kinds of changes occur at the electrodes: first, changes in the concentration of ions, and second, a withdrawal of charges from the ions which come in contact with the electrode. It will be necessary to decide which of the two physical effects of the current is responsible for its physiological effects at the electrodes. Experiments which I published eight years ago† prove conclusively that the contraction caused by the making or breaking of a galvanic current cannot be caused by a withdrawal of charges from the ions. In these experiments I showed that a nerve which is entirely insulated and placed parallel to the spark discharge of a Toepler-Holtz machine or a Ruhmkorff will cause contractions, whenever a spark or a discharge is produced, while no or only minimal effects are noticeable when the nerve lies at right angles to the spark discharge. Since the same influence of the orientation of the nerve to the direction of a galvanic current has been known to exist when the current passes directly through it, it follows that the stimulating effects of a current are not due to a withdrawal of the electrical charges from the ions at the electrodes, but are due merely to a change in the concentration of the ions at the electrodes (or wherever the motion of ions is blocked inside a living organ). For in my experiments no electrical charges were withdrawn from the nerve, and the only effect the induction could have produced was a change in the concentration of the ions at the two sides of the nerve opposite the electrodes of the Ruhmkorff or Toepler-Holtz machine.

It is therefore obvious that no explanation of electrical stimulation can be correct unless it is based exclusively upon the effects which changes in the concentration of ions will produce. This eliminates such hypotheses as the one which assumed that protoplasm consisted of positively charged colloidal particles and that a loss of this charge at the cathode produced coagulation. It eliminates likewise all hypotheses which are based upon the assumption of secondary chemical effects due to the withdrawal of charges from the ions and subsequent chemical reactions caused by the transformation of ions into atoms.

It was clear to me that a solution of the riddle of the stimulating effects of the galvanic current could only come from a study of the effects of solutions of electrolytes upon nerve and muscle. When we put a nerve or a muscle into a solution of an electrolyte, the ions of this electrolyte will migrate into the nerve or muscle, and an increase in the concentration of the ions of the electrolyte in question will be produced. I therefore endeavored to find out which solutions of electrolytes allowed us to imitate the various effects of the galvanic current upon nerve and muscle.

Since the stimulating effects of the current and the increase in irritability (catelectrotonus) occur at the cathode (when the current is made), and since the cations migrate to the cathode, I expected—as was perhaps natural—to find that certain of the cations present in the muscle and nerve were responsible for the catelectrotonic effect of the current and the production of twitchings by the same. The cations which were concerned were Na, K, Ca and Mg. I found that when the chlorides of these four metals are used NaCl and KCl cause rhythmical twitchings when a frog's muscle is put into a solution of one of these salts; in a m/8 solution of the former the twitchings may last for two days while in a pure KCl solution only a few, often only a single contraction of the muscle occurs at the moment it is put into the solution. But no condition resembling catelectrotonus is produced in the muscle. The chlorides of Mg and Ca, on the contrary, not only produce no contractions of the muscle but inhibit them when they are produced by NaCl. When I put the nerve into any of these four solutions (isotonic with the blood), no condition resembling catelectrotonus was produced and no twitchings occurred during the time of my observation.* The only application that could be made from these facts to the theory of electrical stimulation was this, that possibly the single contraction which starts from the cathode when the current is made might be due to the K ions. Since the migration velocity of the K ion is greater than that of the other three inorganic cations named, the making of the current must indeed increase the concentration of the K ions comparatively more at the cathode than that of any of the other three ions. I expressed this possibility in my lectures in Chicago, but never published it because the most essential feature of galvanic stimulation could not be explained in this way, namely, the increased irritability in the region at the cathode (catelectrotonus) and the decreased irritability at the anode. Moreover contractions could be produced by KCl in the muscle only but not from the nerve.

The fact that Ca and Mg inhibit the stimulating effect of NaCl suggested the idea of testing the effect of such sodium salts whose anion is liable to precipitate calcium (or Mg) or to form calcium salts with a comparatively low degree of dissociation. It was found that such salts not only produce rhythmical contractions but that they do so at a much lower concentration than NaCl. Moreover such salts, e.g., oxalates, fluorides, phosphates, citrates, etc., are liable to increase the irritability of the muscle in a striking way and produce in it a form of irritability which I called provisionally contact irritability. I found that these solutions acted in a still more striking way upon the nerve inasmuch as they produce here an increase in irritability, such as exists in the region around the cathode.† It is astonishing how rapidly such an increase is brought about in a nerve when put into the solution of a calcium precipitant, such as sodium fluoride, citrate, etc. I have described in the last mentioned paper several experiments which indicate how enormously sensitive the motor nerve becomes under this condition.

The further extension of experiments showed that the condition of increased irritability can be produced by the salts which precipitate calcium not only in the nerve and muscle of higher animals, but also in the lower forms, e.g., the isolated center of jelly fish.

It is an equally general fact that when this condition is produced in a nerve, muscle or any other organ tried thus far, the normal or diminished irritability can be established by adding a sufficient quantity of $CaCl_2$ or $MgCl_2$ to the solution, or better still by putting the nerve for a short time into a pure solution of one of these salts.

The result of these experiments has therefore been that an increase in free Ca or Mg ions in the nerve or muscle causes a condition of diminished irritability corresponding to the anelectrotonus caused by the galvanic current, while a decrease in the concentration of free Ca or Mg ions causes a condition of increased irritability corresponding to catelectrotonus caused by the galvanic current.

The question therefore presented itself: could it be possible that the effect of the current consists in increasing the relative concentration of the free Mg and Ca ions at the anode and decreasing it at the cathode? I think it can be shown that at the cathode similar effects may be produced by the galvanic current as when we put the nerve or muscle into a solution of a calcium precipitant (or a salt whose anion forms a Ca salt with a small degree of dissociation) while at the anode effects must be produced similar to those which we obtain when we put the nerve or muscle into a $CaCl_2$ or $MgCl_2$ solution.

The changes in the concentration of the various ions which will occur in a nerve at the electrode depend primarily upon the velocity of the migration of ions. This velocity varies considerably for the anions found in nerve and muscle. While the Cl ion has a very high velocity (65.4) the higher fatty acid anions, such as oleate, have a very small velocity, probably below 30. The same must be true for palmitate and stearate. These anions of the higher fatty acids must be found in the nerve and muscle. It is known that these anions precipitate Ca and it has been shown directly by Friedenthal* that sodium oleate acts like sodium oxalate and sodium fluoride in the production of muscular twitchings and otherwise, when injected into an animal. On account of this enormous difference in the velocity of the Cl and oleate ions, the galvanic current must cause more Cl ions to leave the cathode in the unit of time than oleate, palmitate, etc., ions and consequently, in the region of the cathode, the current must bring about a relative increase in the concentration of the Ca precipitants such as oleates, etc., and a relative decrease in the concentration of $CaCl_2$, which is not only very soluble, but also highly dissociated. It is therefore obvious that the effect of the galvanic current at the cathode region must be the same as if we put the nerve into a solution of sodium oxalate, fluoride, citrate, etc. At the anode just the reverse must occur. In the unit of time comparatively more Cl than oleate ions must migrate and collect there and the result will be an increase in the concentration of free Ca and Mg ions.

We have only discussed thus far these few anions, inasmuch as we cannot speak with equal certainty about the velocity of migration of other anions in the nerve or muscle. It is known that CO_2 is formed constantly in the muscle. This formation of CO_2 must of course increase the amount of Ca held in solution and increase the concentration of the free Ca ions through the formation of the bicarbonate of Ca. It is therefore of interest to state that according to Kohlrausch the velocity of the CO_3 ion (and HCO_3?) seems to be comparatively great, even greater than that of the Cl ion, the former being 70, the latter 65.4.† The figure for CO_3 is however not considered as correct as that for Cl. It seems certain, however, that the CO_3 ions have a comparatively great velocity and their relative concentration will therefore be diminished at the cathode and increased at the anode. No reliable data seem to exist concerning the velocity of the PO_4 ions.

As far as the changes in the relative concentration of the cations at the two electrodes are concerned, they must be less than the changes in the relative concentration of the anions, inasmuch as the difference in the velocity of migration of the cations is considerably smaller than that in the migration of the anions. The velocity of Cl is more than twice, possibly three times as great as that of the oleate ion and is absolutely greater than that of any of the cations K, Na, Ca, and Mg. The relative velocities of these ions are for K = 64.7 for Ca 51.8, for Mg 46, and for Na 43.6. Since K is by far the fastest ion, the main effect will consist in a relative increase in the K ions at the cathode. The difference in the velocities of Ca, Na, and Mg is too slight to bring about marked and rapid changes of their relative concentration at the electrodes under the influence of a weak current such as is used to produce electrotonus. It thus seems as if the differences in the relative migration velocities of the four cations mentioned above could not contribute materially to the origin of the electrotonic conditions.

While the data in our possession at present seem to explain satisfactorily the origin of the anelectrotonus and catelectrotonus, they do not show why only at the making and breaking of a current a contraction occurs. It is possible that the two phenomena are only incidentally connected.

If we summarize the facts discussed in this paper we may say: that previous work has shown that the condition of catelectrotonus (increased irritability) can generally be produced by putting nerves or muscles into a solution of calcium precipitants such as sodium (oxalates, fluorides, citrates, oleates, etc.) and that a condition of decreased irritability can be produced by putting the nerves or muscles into solutions of $CaCl_2$ or $MgCl_2$.

This paper indicates that by considering the migration velocity of the various anions in nerve or muscle it can be shown that if we send a galvanic current through a nerve or muscle, at the cathode the concentration of those anions which are liable to precipitate Ca, e. g., oleate, is relatively increased, while that of the Ca solving ions, like Cl, is decreased; and that the reverse is true at the anode. It seems therefore as if the electrotonic effects of the galvanic current might be due to the comparative increase in the Ca precipitants at the cathode and the comparative increase of the Ca solvents at the anode.

* Reprinted from the University of California Publications.

† Loeb, Pflüger's Archiv, vol lxvii., p. 483, and vol. lxix., p. 99, 1897; and reprinted in Studies in General Physiology, vol. ii., p. 482, 1905.

* The results of these experiments were published in the Festschrift für Prof. Fick, Würzburg, 1899, where I mentioned also briefly the negative results I had obtained in regard to the nerve.

† Loeb, American Journal of Physiology, vol. v., p. 362, 1901. Also in Studies in General Physiology, vol. ii., p. 692.

* Friedenthal, Engelmann's Archiv, p. 145, 1901.

† These figures are quoted from Landolt and Börnstein, Tabellen, p. 753.

A NEW STANDARD OF LIGHT.

PROF. J. VIOLLE, as is well known, suggested choosing as a standard of light the radiation given off by the surface unit of incandescent platinum at its point of solidification. This French scientist has recently been experimenting with a view of establishing a new secondary standard of light on a similar principle. Without altering the fundamental standard just referred to, he found it profitable to take advantage of the normal boiling of a metal to maintain the temperature of a vessel heated by vapors of this metal, at a constant figure. To this effect he arranged a kind of testing tube of carbon above the metal, which was brought to the boiling point in the electrical furnace. The vapor would surround the whole of the bottom and a considerable length of the test-tube, which was lengthened by a tube allowing the interior of the test-tube to be investigated at constant temperatures.

Several metals were tested, among which were silver and copper, and the testing tube was given different shapes so as to obtain a double vapor sheath around it. Electrical heating both by alternating and direct current was made use of, the former type of current being found better in distributing the heat and less wearing for the crucibles. A practically constant radiation was thus obtained and maintained, while only a few difficulties are still to be overcome to give this light standard a practical form.

METHODS OF TRANSPORTATION AMONG INSECTS.

ALTHOUGH ignorant of the beauties of the taximeter, certain insects have found the means of having themselves carted about without fatigue to the exact place to which they wish to go, and that, too, without giving any order to their driver, who is at the same time their horse. A few examples will make the subject better understood than the above brief statement, which is not so fanciful as might be supposed. There are, however, several cases to be considered. In the first, the insect that causes itself to be carried has merely momentary relations with the one that carries it, and abandons it when it has reached its destination. This is what is done by many Acarids, which afford an example of slowness personified. When the environment in which they live is exhausted, and when they see the period approaching in which they will no longer have anything to eat, they fasten themselves to some part of a passing animal—the hairs of an insect, the plumage of a bird, or even the clothing of a human being—and remain thereon until they meet with a place favorable for obtaining food. This explains the fact, many times noticed, that Acarids are met with which apparently live as parasites on animals, while in most cases they are not, but really live on matter in a state of decomposition. They are in reality false parasites which merely require their host to carry them. Among the species that most readily adopt this mode of transportation may be mentioned the Gamasids, which, in the chrysalis state, fasten themselves to the body of Coleoptera, and which every collector has met with in abundance upon the *Necrophori* and *Geotrupes;* the female *Holostropis*, which knows enough, when she wishes to disseminate her eggs, not to cause herself to be carried about until after she has been fecundated; the *Uropodes*, of which the chrysalides fix themselves by an anal mucosity that hardens into the form of a peduncle; and the *Tyroglyphs*, which, in the chrysalis state, very easily fasten themselves to any animal whatever through a special suction apparatus with which the under part of the abdomen is provided.

To the same category belong the pseudo-scorpions, which suspend themselves from the legs of flies; the *Lentinus testaceus*, a coleopter which houses itself in the fur of small burrowing mammals, such as moles and field-mice, in order that it may be carried into the nests of bumble-bees; and the *Limosina sacra*, an Algerian fly, which, according to MM. Lesne and Chobant, causes itself to be carried by *Scarabæi* during their flight to excrement, which these coleopters use for forming a ball.

The second case to be considered is that in which the objective point of the insect carried is the carrier's nest which it desires to plunder. The best example of such insects is found among the Meloidæ, a family which embraces insects of an extremely repugnant character, and which crawl along the ground and have merely insignificant elytra and a large and heavy abdomen that excites disgust even among the most enthusiastic entomologists. In order, perhaps, to still further increase their offensiveness, they exude, when captured, an abundance of a red liquid which is nothing more than their blood and which stains the fingers. The motion of the Meloidæ is exceedingly slow because they have to drag the heavy weight of their abdomen, and also because they are lazy by nature. It takes them several minutes to move a leg, and every effort seems to exhaust them. They are not spoken of in this article because they have found a means of having themselves carried, but because they, who are themselves almost cripples, take measures to provide long circuits for their young. The manner in which the latter succeed in carrying out the designs of their mother is as follows: The eggs are deposited in small bunches in a hole formed in the ground at the base of a plant, and are then covered by the insect with a little earth. That is all the trouble that the female takes to preserve her species, but, in justice to her, it must be said that she "gives good measure," since the naturalist Newport has calculated that the *Meloe proscarabæus* lays at least 4,220 eggs.

The hatching takes place in May or June. From every egg there issues a small louse-like larva which a short time afterward is found installed in the hair of bees. For this reason, it was once called the "bee louse," and no one had any suspicion that it had any connection with the *Meloes*. But the observations of Newport and Fabricius have removed every doubt on that score. At the moment of hatching, the larvæ, which are very agile, crawl over flowers and blades of grass, whereon they sometimes swarm. Upon the capitulum of the chamomile, for example, we may find ten, fifteen, or more of them half concealed in the throat of the florets or in the interstices thereof; and it requires sharp eyes to detect them, since the amber color of their body matches the yellow tint of the florets. If nothing extraordinary occurs on the capitulum, if a sudden vibration does not announce the arrival of a foreign host, the Meloes remain totally immovable and give no sign of life. To see them plunged head foremost in the throat of the florets, one might be led to suppose that they were in search of nectar; but in such an event they would have to pass frequently from one floret to another, which is something that they do not do, except when, being called forth by a false alarm, they seek a new hiding place or another floret that appears to them more favorable. Although their immobility is complete, nothing is easier than to awaken their suspended activity. If we shake a chamomile flower slightly with a straw, the larvæ will instantly leave their hiding places and advance from all directions to the white ligulate flowers of the circumference and traverse them from one end to the other with all the rapidity that their small size permits. Upon reaching the extreme end of the flowers, they will fix themselves thereto by means of their caudal appendages or perhaps by means of a special viscosity, and, with the body hanging outwardly and the six legs free, they will undergo flexions in all directions, and stretch themselves as much as possible, as if they were endeavoring to reach some remote object. If nothing that they can seize presents itself, they will regain the center of the capitulum, after a few vain attempts, and soon resume their immobility. But if the capitulum is visited by an insect, the larvæ at once make for it and affix themselves to its hairs. And so it is possible to find them on a large number of species of insects to which they remain attached in a state of complete immobility. Many of these larvæ are destined for certain death, and this explains why it is that so many eggs are laid by the female Meloe. The only ones that escape death and become capable of ulterior development are those that have been led by chance (for their instinct is not perfect) to affix themselves to bees of the genus *Anthophora*, which form subterranean cells that they fill with honey and deposit thereon a single egg. When the bee reaches its nest, the larva of the Meloe ("triongulin," as it is called) quickly deserts its host and takes possession of the egg, which it hastens to devour and then attacks the honey, and, finally, through a complicated metamorphosis, becomes an adult Meloe.

Fig. 3.—*Meloe proscarabæus* upon flowers, and its young, or triongulins. A larva, enlarged, in the left-hand corner.

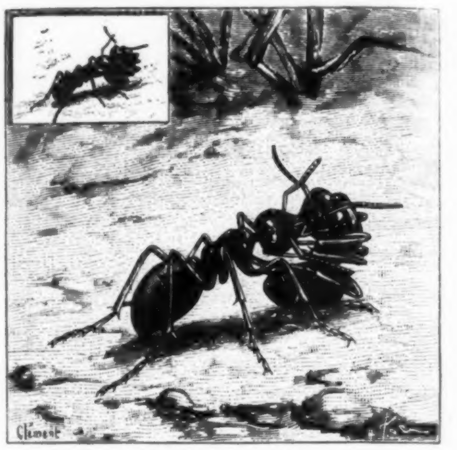


Fig. 4.—Red ants (*Formica rufa*). The same of natural size in the left-hand corner.

The Meloes are not the only insects that cause themselves to be carried with the most sinister motives. We may mention as belonging to the same category the coleopterous *Antherophagi*, which, in the adult state, fasten themselves by their mandibles to the legs, antennæ, and proboscis of the bumble-bee, in the nest of which are developed their larvæ, as well as the chrysalides of certain Acarids of the family *Sarcoptidæ*, which attach themselves to the hairs of nest-building hymenopters in order to reach the nest of the latter.

The third case to be noted is that in which the result of the transportation is to render it unnecessary for the insect carried to follow the host in its peregrinations. In this category is included the ants that carry each other by means of their mandibles when they leave their domicile in order to seek another formicary, and in assuming particular and well defined positions, according to the species.

The millipeds, also, that inhabit formicaries affix themselves to the ants at the moment of a general "house-moving," and thus reach the new domicile without any trouble. For example, Lund observed some ants of the genus *Myrmica* moving in a procession and having a singular gait, due to the fact that each insect carried under its abdomen a milliped that clung thereto by its legs. As the milliped was larger than the ant, the latter, in walking, was obliged to spread its legs wide apart, and this naturally gave it an odd gait. Finally, we may mention cases of indirect carriage, a good example of which is mentioned by M. Charles Janet, who one day collected some yellow ants in which numerous Acarids (*Uropoda anticeps*) had fixed themselves upon the cocoons that the ants were carrying with their antenniform legs. Thus installed, the Acarids were carried every time that the ants passed from one stone to another that was better exposed.—Translated from La Nature for the SCIENTIFIC AMERICAN SUPPLEMENT.

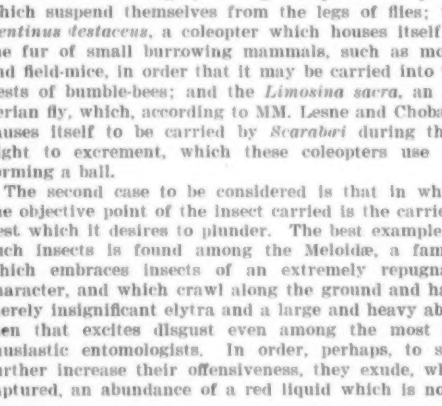


Fig. 1.—*Geotrupes mutator* carrying Gamasæ, one of which is shown in the upper left-hand corner.

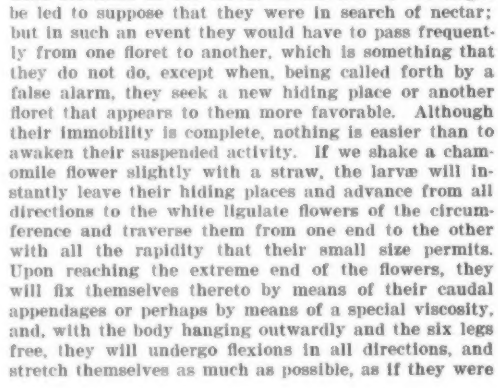


Fig. 2.—Scarabæi (*Ateuchus laticollis*) rolling their ball and carrying *Limosinæ Sacræ*, one of which is shown on a large scale.

A NOVEL METHOD OF DETERMINING THE ELEMENTS OF THE EARTH'S ORBIT.

By OUR BERLIN CORRESPONDENT.

PROF. KÜSTNER, Director of the Bonn Observatory, has recently determined the elements of the earth's orbit on a spectrographical method, which may be called a departure in astro-physical practice.

Any motion occurring in space, provided it effects an increase or decrease of the distance between the heavenly bodies and the terrestrial observer, is known to produce a displacement of the spectrum lines controlled by the Doppler principle. It may thus be ascertained that while some fixed stars are approaching toward the solar system, the distance of others continually increases, according as the spectrum lines as compared with those of chemical elements are seen to be displaced either toward the violet or toward the red end. These displacements are periodical in spectroscopic double stars. It should, however, be taken into account in similar determinations that the earth rotates round the sun at a speed of about 30 kilometers per second, producing a yearly periodicity in the displacement of the lines, while in connection with more accurate work even the earth's rotation round its axis should be considered, though this be extremely slow even at the equator as compared with the speed of light. Prof. Küstner undertook to ascertain the speed of revolution of the earth, from the periodical displacement observed in the lines of some suitable star. Such a star should be relatively near to the plane of the earth's orbit in order to undergo considerable displacements. It should moreover be of sufficient luminous intensity, while its spectrum should contain a good series of lines readily susceptible of determination. These conditions have been found by Küstner to be so well complied with in the case of Arcturus, as to in-

duce him to utilize a set of observations made on the spectrum of this sunlike star for determining the *speed of the earth.* From June 24, 1904, to January 15, 1905, as many as eighteen suitable photographic plates were obtained, all of which had been exposed an hour after the star referred to had traversed the meridian, i. e., shortly after dusk in summer and shortly before dawn in winter. Special precautions had to be used in obtaining the arc spectrum of iron which was to serve for comparison. Sixteen lines of iron were chosen.

The spectrographic lines were measured on each of the plates under the microscope. While the calculation based on the relative speed of the earth in regard to the star in question, as resulting from these measurements, is comparatively simple in itself, disturbances were caused by the moon's revolution round the earth, and even the disturbance produced on the sun by the powerful planet Jupiter had to be considered in order to obtain really accurate results; the disturbance due to Saturnus might as well be taken into consideration.

What is called the constant of the earth's speed of revolution was eventually obtained at 29.617 kilometers per second, with a probable error of $\pm$ 0.057 kilometer. As the displacements of the lines give the ratio of the earth's speed to the speed of light, this figure implies an hypothesis in regard to the speed of light; according to the best of recent physical determinations this speed was taken at 299,865 kilometers per second, with a probable error of $\pm$ 26 kilometers.

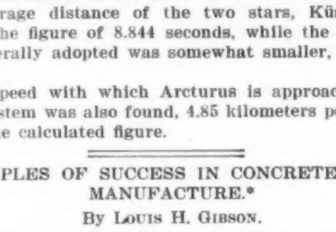
As regards the parallax itself, viz., the angle under which the radius of the earth is seen from the sun at the average distance of the two stars, Küstner obtained the figure of 8.844 seconds, while the figure so far generally adopted was somewhat smaller, viz., 8.80 seconds.

The speed with which Arcturus is approaching the solar system was also found, 4.85 kilometers per second being the calculated figure.

PRINCIPLES OF SUCCESS IN CONCRETE BLOCK MANUFACTURE.*

By LOUIS H. GIBSON.

THE average man can make a first-class cement block if he will. The average worker does not make a first-class cement block, by any means. This is proved by the fact that most architects are afraid of cement in this form. Architects are not afraid of cement in any other form. For many reasons they are distinctly favorable to it in any other forms than blocks. It is

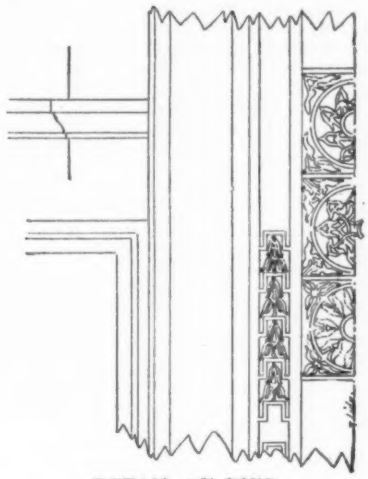


PIER SECTION.

just as well for us to acknowledge this fact. The fault is not in the architect. It is in the block, and behind the block is the man. Now, the man can make a first-class block and make money thereby if he will. There is no more convenient form in which to handle concrete as a building material in upper walls than in blocks. This is the reason that the cement block has met with so much popular favor, notwithstanding the fact that the work of block making has often been done so badly. The builders of houses, the people, recognize the inherent merits of cement and concrete, and because of this fact the cement block idea has met with really more success than its makers deserve. If the cement had had a harder fight for existence it would have been better for the block and eventually better for the pocketbook of the maker of the block and the machine. The past will have to be lived down.

We must make a block of good form with clean, sharp edges, good external texture, interior composition which leaves nothing to be desired, pleasing color, good and varied design. The block must be such a one that the moisture will not penetrate it. The maker of the block must be able to lay out his work from a set of plans and number his blocks to conform to a setting plan, so that they may be taken to the building and placed in position like the stones of Solomon's temple, without the sound of the hammer. The average man can make this kind of block if he will, but the will must be an active, all-day, all-the-week and all-the-year will. There is no limit to the stability or structural usefulness of the concrete block. Its form is pliable and its possibilities of beauty are great. There is no color so rich, none so beautiful, none so sedate or dignified that it is not capable of expression and permanent representation in some form of concrete. The view of the future is distinctly encouraging.

We must first learn to make the ordinary cement block and make it well. Now the material so badly composed and badly mixed comes out of the machine with surfaces none too even, edges not clean and sharp and is often badly handled after it leaves the machine. We hear a good deal of talk about the proportion of mixtures; we hear of one to five, and one to four, and one to two, and all that. Some of us fix in our minds certain arbitrary standards. There can be no fixed proportion of cement if one desires to secure a fixed and uniform result in the block. The sand may be ever so sharp and clean, but if it be not properly graded, from the very coarsest to the very finest, the proper results will not be secured. The true basis of proportion in the mixture of concrete is in the voids, and the proportion of voids is determined by the proper grading of the sand. The ideal concrete is made when the proportion of voids is reduced to the minimum. This can only be done through the use of the proper amount of fine as well as coarse in the graded sand. In certain communities sand is pumped from the river and from pools and pits. In this way it is very easy to grade it either by gravity devices or by sieves, so that there are fine and coarse sand and large and small gravel. The



DETAIL OF PIER.

coarser sand, often taken out by screening, presents at first sight a very beautiful appearance. But the trained architect, builder or concrete worker, on closer examination, realizes that he has a very deceitful material and that an undesirably large proportion of cement will be required to make concrete out of this apparently pleasing material. Enough cement would have to be put in to fill the voids left by the fine sand taken out. The ideal block will have the sand, coarse and fine, properly graded, properly mixed and proportioned from the finest to the coarsest, not only on account of the excellence of the block, but as well on account of economy in the use of cement. The aggregate should be mixed dry, preferably by machine, and afterward, in the same manner, with more water than is now used. The success of the bitulithic pavement, which is unquestioned, is largely on account of the grading of its aggregate.

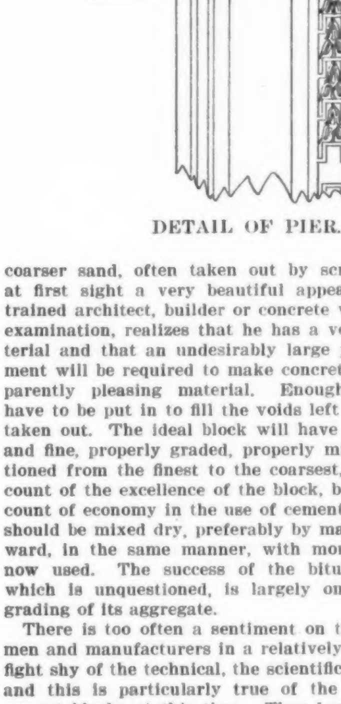
There is too often a sentiment on the part of workmen and manufacturers in a relatively new industry to fight shy of the technical, the scientific and the artistic, and this is particularly true of the manufacture of cement blocks at this time. They have been educated through various sources to believe that the one thing necessary is to make a block, and that the people will buy it, and that they will make money thereby. In some respects this opinion has been justified in the past. More blocks have been sold than their merit warrants. At present this condition is not so apparent. There is more discrimination, there is more hesitancy and there is more prejudice against the block than there was during its earlier history. The distinguished architects are, almost to a man, against it. However, with the architects this matter is not so serious as with the general public. As soon as the properly made block is conspicuously on the market, and as soon as the manufacturer has mastered the structural and artistic difficulties in the way of its production and use, then it will be found that the architect is ready to face about and proclaim to his client and the world that a new architectural medium is at hand and thereby influence the public in the matter. A few carefully designed buildings, carefully executed, will very soon remove all of the prejudice on the part of the people, the architect, and the builders which now exists against their use.

It is within the memory of all of us when the brick-makers' work was a small roadside industry. There was the mud pit, the tempering wheel and the mule, the molder who worked at a table, and his off-bearer. There was hard work, a crude product, and little profit. Through the aid of the engineer, the architect, the artist and the systematic business man we now have a great manufacturing industry, where the amount of hand labor is reduced to a minimum and where, through the aid of scientific methods, results are exactly and definitely predetermined. We have technical schools devoted to clay-working, and they call to their aid the various branches of science, and the general technical schools are contributing their part to this great industry. The block-making industry must progress along these lines, and while it may appear that there is rather a wide separation between this work, which is so often crudely carried on, and that of the scientist and technical school, yet we have the precept and example of the brick-making industry to guide us. The way from the muddy roadside industry of the clay-worker to the technical methods of recent years is much farther than from the cement-block maker's plant of to-day to a condition that the inherent merit of this material justifies. The chemistry of cement is well understood, and certain of the methods of concrete making have been fairly worked out among a limited number of people. But to say that the art of concrete mixing has been fairly well mastered by any large number, or that it is fairly well understood among any large proportion of block makers, would be erroneous. A large part of the trouble on account of absorption is because of lack of knowledge, of practice, on the part of block makers.

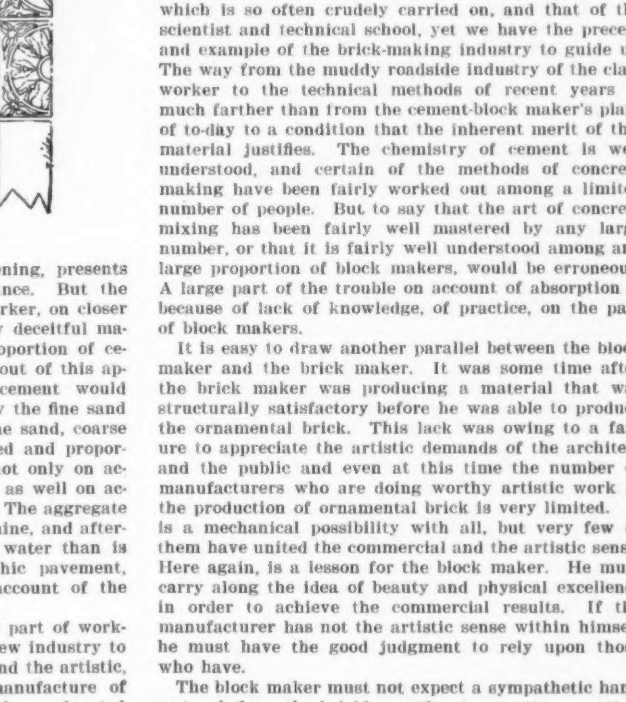
It is easy to draw another parallel between the block maker and the brick maker. It was some time after the brick maker was producing a material that was structurally satisfactory before he was able to produce the ornamental brick. This lack was owing to a failure to appreciate the artistic demands of the architect and the public and even at this time the number of manufacturers who are doing worthy artistic work in the production of ornamental brick is very limited. It is a mechanical possibility with all, but very few of them have united the commercial and the artistic sense. Here again, is a lesson for the block maker. He must carry along the idea of beauty and physical excellence in order to achieve the commercial results. If the manufacturer has not the artistic sense within himself he must have the good judgment to rely upon those who have.

The block maker must not expect a sympathetic hand or touch from the bricklayer, the stone cutter or setter. It is to the interest of the block maker and the block business that he see his material set properly in position in the finished building. It is upon the reputation of the block thus established that the business life and welfare of the block manufacturer and the machine manufacturer must rest. After all, it is a question of the block in the wall as to whether the owner is pleased with it and as to whether the public is pleased. Public opinion is built upon the performances of the past, and not upon hopes as to the future.

Far be it from the writer to utter one discouraging word in connection with this great industry. All that is said is said in a spirit of helpfulness. If he did not know that satisfactory blocks were being made, and did



DETAILS OF WALL SECTION.



CEMENT BLOCK STORE FRONT.

* Municipal Engineering.

not believe that many more will be made there would be no effort on his part either to criticise or to foster this industry. It is only criticised because of the realization of the great and prosperous future which is before it. The average man can make the good block and he can get it into the building in a satisfactory way if he will.

The design which is here given is of a small store front. It may be erected in brick, which is a burned-clay block. It may be erected in terra cotta, which is another form of burned-clay block. It may be erected with blocks of stone. As herein detailed and as conceived it may be executed quite as well in cement blocks. From the standpoint of design and execution terra cotta, brick and cement blocks are closely allied. Nearly all the forms of terra cotta construction are so made that they can be molded in flasks in practically the same manner as cement blocks, excepting that terra cotta work is nearly all done by hand and the cement block work is practically all done by machinery. The photograph of the decorative forms of this design is taken from the plaster casts, and, being of plaster drawn from the molds, is clear enough evidence that they could be executed and cast in concrete. As to whether they can be cast by machinery or not is purely a matter of business. If it pays to cast them by machinery, all well and good. If not, cast them in forms by hand. It is a mechanical possibility to cast them by machinery in the same way that other cement blocks are made. The plasters of the size shown are of the blocks indicated in the photographs. If desirable for business reasons they could be jointed differently. This would be largely a question of shop practice. No two terra-cotta factories would adopt exactly the same plan of jointing on the same job. The way this sort of thing is ordinarily done is to take the architect's plans and details and make a shop plan indicating jointings and certain structural details. This is submitted to the architect for approval and suggestion, and as a result of conference it sometimes happens that changes are made to the mutual satisfaction of both parties. Terra-cotta workers are especially skillful, unusually competent and full of resource in matters of this kind, and the competent and experienced architect is always glad to avail himself of the suggestions of these specialists so long as they in no way suggest changes or undertake in any way to interfere with dimensions, forms or the artistic elements of the design. The terra-cotta establishment is thus referred to because in shop methods, and especially those which relate to the laying out of the work from the drawings, it is closely allied to the necessities of cement-block making. The block maker can learn a great deal from a terra-cotta factory. There is no class of men in the building business who are more systematic, thorough or who have more fully mastered the technicalities of their business than the terra-cotta superintendents. The block maker, however small his business, will find it to his interest to systematize his work along the general lines of the terra-cotta factory. It predetermines accurately all costs and anticipates all structural contingencies. It locates definitely all lines of responsibility as they affect the interests of the architect and the various subcontractors who in any way have relation to his work.

The cornice of this building can be made of cement tiles. The supporting members are of light metal framework. The opening over the store front and those over the windows are structurally carried by steel members. The larger openings are covered with channels and the smaller ones with angles. The determination of their sizes is a very simple matter in engineering requiring only a calculation of the weight of the structural material, which represents the dead load, and an allowance for whatever live load there may be superimposed. There is no part of the work of using cement blocks structurally which has brought the business generally into greater disrepute than the clumsy methods which have been frequently employed about door and window openings. More cement-block buildings have been botched at this point than by any other structural errors. The jointing of this design is a very simple matter and could be subject to some latitude without in any way affecting the integrity of the design. No pitched faced blocks are used in any part of this work.

USE OF DIAMONDS IN THE INDUSTRIES.*

By DR. GEORGE F. KUNZ.

DIAMOND TOOLS.

THE subject has been treated in a recent paper on diamond tools in general, presented to the American Society of Mechanical Engineers at its meeting in New York in December, 1904, by Mr. G. C. Henning.† In this communication the whole subject of diamond tools is concisely reviewed, and the number and variety of such appliances are strikingly set forth. Besides the familiar uses of steel drills and saws and of cast-iron disks charged with diamond dust for cutting and polishing diamonds and other hard gems, of carbon drills, and of saws for hard stones, etc., Mr. Henning notes several other appliances. Among them are the uses of diamonds by lithographers, engravers, and scale makers for extremely fine lines requiring great accuracy and sharpness, for which no other material is found adequate; for drilling glass and porcelain; in dentistry for drilling teeth, especially artificial ones; for bearings in watches; and particularly for bearings in electric meters, where they cause a minimum of friction and last for many years.

Many interesting details are given by Mr. Henning as to the manufacture of diamond tools. He emphasizes the fact that diamonds can be electroplated like metals; this property is made use of in what is termed their galvanoplastic setting. The diamond to be set for a tool is first plated, and then metal can be cast around it, which alloys with the plating and gives a perfectly firm solid mounting.

In most cases the diamonds for accurate work are "shaped," by cutting and polishing, into forms like those of the tips of ordinary steel tools. Several of these forms are figured. For drilling glass or china a triangular splint is provided with a flat, triangular, pyramidal point, which, with turpentine or a lubricant, is found more effective and more enduring than any other instrument. Other forms have round, sharp, or square terminations for different uses and substances. For turning and finishing articles of hard rubber and in working carbon for electrical purposes diamond tools are almost the only ones available. In addition to their much longer life, their resistance to the heat produced by friction renders them immensely superior to steel tools, and hence they can be operated at far greater velocities. Dental tools are not shaped, minute chips being simply soldered into steel shanks.

Diamonds for Wiredrawing.—For wiredrawing, a diamond is first drilled through with a hole of the proper size, tapering from each end, and well polished. Steel is cast around the diamond to prevent its bursting, and bronze is then cast around the steel to protect it from corrosion by the lubricating substances employed in the drawing. The hole is rarely larger than 0.064 inch; as for coarser wires a steel drawing plate is deemed accurate enough and diamond plates would be needlessly expensive. From this size the tools vary down to 0.001 inch, although Mr. Henning states that occasionally they are made to order as small as 0.00045, 0.00055, and 0.00065 inch. The holes are made accurate to 0.0001 inch; this is particularly mentioned, as being perhaps doubted by those not familiar with the subject.

For copper, a rough wire of 0.072 inch is drawn first through a 0.064-inch diamond plate; then successively, for finer sizes, through 0.053, 0.045, 0.040, 0.036, 0.032, 0.028, 0.025, 0.022, 0.020, and 0.019 inch, and then by thousandths down to 0.0075 inch, and by half-thousandths down to 0.001 inch.

The wear on the diamond increases in the following order, with different metals: Gold, silver, copper, brass, bronze, platinum, soft steel, nickel, iron, and crucible steel (piano wire).

It is essential in electrical apparatus that the wire should maintain absolute uniformity in shape and caliber to secure constant exactness in resistance and in the distribution of weight about spindles, etc. Hence diamond drawing plates have come into much greater use of late, because the rapid wear of steel plates caused irregularity in the size and the shape of the wire.

Diamond Saws for Stonecutting.—The use of diamond saws for cutting stone was mentioned, at the time when it first became at all prominent, in the report of this Bureau for 1898. Since then its application has extended widely; and a recent communication from the E. C. Atkins Company, in New York, mentions revolving saws manufactured by them on an order from Scotland, and others made or ordered for various places. These saws range up to 75 inches in diameter, and estimates have been made for saws as much as 90 to 98 inches in diameter. One saw of 84 inches was 5/16 inch in thickness and carried 100 diamonds, which weighed together between 25 and 30 carats. These cost over $20 per carat in addition to the setting and fitting, which amounted to $60 more in all. Such saws are run at about 560 revolutions per minute, giving a rim speed of some 12,000 feet. The "feed" or rate of advance into the stone is about 7½ inches per minute in the oolitic limestone of Indiana. These saws are fast replacing the alternating saw, especially in the quarries of that region, for cutting stone into blocks.

* Abstract of a report issued by United States Geological Survey.

† Trans. Am. Soc. Mech. Eng., vol. xxvi., 1904.

THE DEGREE OF ACCURACY THAT CAN BE OBTAINED IN MEASUREMENT.

WHEN the intellectual individual reads of measuring distances comparable with the diameter of an atom, or of pressures, compared with which the tread of a fly is like the blow of a triphammer, the questions naturally arise to his mind: What degree of accuracy can be attained in such measurements? If it is possible to measure to the ten-millionth of a millimeter, is that measurement accurate? Can the length of a bar of iron be determined to that fraction of a meter or inch? It is possible to measure differences of temperature as small as the millionth of a degree, but can ordinary temperatures be determined with such a degree of accuracy? The thoughtless salesman will assure the prospective buyer that a certain steel rule, or thermometer, or set of weights is "perfectly" correct, or "absolutely" correct. A too-confiding public buys in the confident belief that these words are correctly used, but the physicist, who must be a born and bred skeptic, who has suffered by experience, smiles at such statements. For we may paraphrase a famous remark of Maxwell concerning relative and absolute, rest and motion, and say, "only when a person has formed the habit of using words without taking the trouble to form the mental concepts that should accompany them can he possibly speak of perfect or absolute correctness." Literally everything is relative. The "perfect" rule may not have a total error greater than a hundred thousandth of its length. The "absolutely correct" thermometer will be pretty sure to have errors of several hundredths of a degree, and the set of weights will be relatively no better. The trained salesman confronted with these facts glibly shifts to the statement that they are "correct enough for all practical purposes."

This brings up the question as to what is "accurate enough for all practical purposes" and what is "as accurate as possible." In general, it is sufficient to know that the distance from New York to Philadelphia in a straight line is, say, 83 miles; but the moment greater accuracy is desired, better specifications are necessary. It must be stated where the distance measured starts in New York and where it ends in Philadelphia. If we say from City Hall to City Hall, then the distance can be stated to a small fraction of a mile; if from center of dome to center of dome, then a few inches would represent the uncertainty. If a particular small point in each building is chosen, then the modern methods of triangulations would give the distance to a small fraction of an inch. Only a few hundred years ago a distinguished German writer on scientific subjects wrote, "If you would determine the foot by the true and lawful method and according to scientific usage, you will station yourself at the door of the church of a Sunday afternoon and select sixteen men—the large and the small—as they come out after the service, and place their left feet in a line, and the distance so measured is the true and lawful rood (rod) for the measurement of land, and one-sixteenth thereof is the true and lawful foot." This was "scientific" accuracy only a few hundred years ago, and is "practical" accuracy to-day for some things.

Tradition says that the English yard was originally the distance from the tip of the nose to the end of the extended thumb of some old Saxon King. King Edgar decreed that the "Winchester" yard should be the standard everywhere. From a metal bar concerning whose physical constants nothing was known, on which were large, crude marks (for such were the imperial yards in the days of Queen Elizabeth), down to the latest prototype yard, which is the distance between two microscopic lines upon a bar whose physical properties have been most elaborately determined. These standards represent very well the development of accuracy in length measurement since the time of Elizabeth. Then an accuracy of a few thousandths of an inch in the length of a yard was ample for any one. This corresponds to about the twenty-thousandth part of the whole distance measured. To-day the imperial prototype yard can be measured to the millionth of an inch at least, and probably its length can be determined with an accuracy of one part in fifty million. This is about the probable error in the comparison among themselves of the "national prototype standard meters" furnished by the International Commission of Weights and Measures at Sèvres, Paris, to the contributing governments.

It was originally intended that the base of the metric system, the meter, should be the ten-millionth part of the distance from the equator to the pole on the meridian of Paris. It was finally realized that every time this distance was measured a different, more correct, value would be obtained, and that absolute accuracy was not attainable. Then scientists very wisely decided to take a particular meter bar as the prototype meter. Hence the standard meter of to-day is the distance between two marks on a particular platinum-iridium bar, entirely analogous to the standard yard. Thus the "three barely corns" which some of us learned "make one inch," have led to a standard yard quite as capable of accurate definition as is the meter.

Science has agreed that light is due to a wave motion in the ether and that the length of these tiny waves determines the character of the color effect produced upon us. Moreover, any chemical element as iron, sodium, copper, etc., when heated under like conditions, will always send out waves of perfectly definite length. Hence these little waves, a sixty thousandth of an inch long, form our best, our most permanent standard of length. By an extremely ingenious research Prof. A. A. Michelson, of Chicago University, determined the length of the international prototype meter in terms of the wave lengths of the light of certain chemical elements. It takes several million such waves to equal a meter in length, and the meter is measured to an accuracy of at least a tenth of the length of a wave of light, or to a relative accuracy of one part in about fifty million. How many people realize that in the sizes of shoes we are still measuring according to the units of the old Saxon kings, and that a pair of children's shoes No. 10 are 10 plus 13 barley corns, or 7 2/3 inches long, and that a man's shoe No. 7 is 7 plus 13 plus 13, or 33 barley corns, or 11 inches long.

Again, whether we consider the imperial standard pound defined by Edward III. as equal to 7,000 barley grains, or the international prototype kilogramme originally intended to be equal to the mass of a cubic decimeter of water at 4 deg. C., in either case we have finally adopted a concrete standard. With all modern improvements, and with the balance *in vacuo*, it is possible practically to weigh to the hundredth or even thousandth of a milligramme (65 milligrammes equals 1 grain). This represents an accuracy of better than one part in a hundred million. Weighing is one of the most accurate operations of science, and yet it is far from "perfect" or "absolute." The grocer of to-day who quotes the price of sugar at so many cents for 7 pounds, or for 3½ pounds, is still using the almost prehistoric standard "stone" of 14 pounds.

It seems ridiculous to talk of the millionth of a degree in temperatures, and yet the bolometer of Langley or the radiomicrometer of Boys or the thermo-pile will measure it with a fair degree of accuracy. We can with such means measure the heat received from a candle at a distance of a mile. Nevertheless, it is practically impossible to measure a single temperature to

thousandths of a degree. Again the relative is easily attainable; the absolute is unattainable.

An idea of practical accuracy may be obtained by considering the results attained by the Coast and Geodetic Survey and the map-making staff of the government. Imagine running a line of levels from the Atlantic Ocean and the Gulf of Mexico to meet a similar line from the Pacific, somewhere in the Rocky Mountains, and when the two lines are found to fail to connect by 8 inches, imagine having confidence enough in the work to seriously discuss what the difference of level between the two oceans might really be. Think of measuring a "base line" several miles long with standard bars 15 feet long kept in ice so as to keep their temperature constant, with such a degree of accuracy that if on the first measurement a pin had been stuck in at the places where the end of the bar came, then on the second measurement the end of the bar would each time fall within the width of a pin of its position on the first measurement. Such accuracy was attained by R. S. Woodward in work for the Coast Survey. What is the use of such accuracy in land surveying? Very little so far as simple questions are concerned; but only such very accurate work can be expected to show the exact configuration of the earth. Is it a fairly true ellipsoid of revolution, or full of bulges and irregularities? The absolute is an unattainable will-o'-the-wisp, but its incessant pursuit leads the scientist to ever higher degrees of accuracy, and every such improvement brings a new crop of contributions to our knowledge, and to the advancement of civilization.—William Hallock, Ph.D., in N. Y. Times.

ENGINEERING NOTES.

It is not practicable to prevent the smoke evil entirely, but only to mitigate it in a degree. Smoke burning, on the other hand, is an impossibility under the conditions which usually present themselves.

A smart railroad performance was accomplished by the Great Western Railroad of England recently in connection with the handling of the American mails. The "St. Louis" reached Plymouth at 12:10 noon on the Saturday, and the Great Western tender for the mails was alongside within five minutes. Although 1,000 bags of mail and parcels post hampers had to be handled, these were landed at the dock 35 minutes later. A special train was in waiting, and this left Plymouth for London at 1:14. The train reached the metropolis at 5:14, the distance of 246 miles being covered without a stop in the remarkable time of 240 minutes—an average speed of 61.5 miles per hour. The performance is additionally notable owing to the numerous heavy gradients that have to be negotiated and the various "service slacks" on approaching crossovers. At places the train attained a speed of 80 miles per hour, and the mails intended for the north and west of England were slipped at Bristol while the train was traveling between sixty and seventy miles per hour.

The first cantilever railroad bridge was the Kentucky River Bridge, of three spans, each of 375 feet, completed in 1877, on the line of the Cincinnati & Southern Railway. Many other cantilever bridges were built thereafter, such as: The Niagara River Cantilever Bridge, on the line of the Michigan Central Railroad, 470 feet span, completed in 1883. The Frazer River Bridge, on the Canadian Pacific Railway, in 1884, 315 feet span, and the St. John's River Bridge, in 1885, 477 feet span. The Poughkeepsie Bridge, across the Hudson River, including a span of 523 feet, finished in 1889. The Colorado River Bridge, at Red Rock, Colo., 660 feet span, completed in 1890, and the Memphis Bridge, with a span of 790 feet, completed in 1892. The latest and most conspicuous cantilever bridges constructed are those over the Monongahela River, on the line of the Wabash Railroad, at Pittsburg, 812 feet span, and at Mingo Junction, 700 feet span, completed in 1904, also the Thebes Bridge, across the Mississippi, 671 feet span, completed in 1905. The bridge over the East River at Blackwell's Island, now under construction, has spans of 984 and 1,182 feet, respectively. The longest cantilever bridge is that across the St. Lawrence River, at Quebec, with a span of 1,800 feet, now being built. This will make it the longest bridge in the world.

The subject of durability is one which ought to be considered in connection with almost every feature in the design of a steam plant. Take the matter of engine speed. Starting with a type of engine which possesses ample strength, the size of it is dependent to some extent upon the speed, and looking at the subject from the single point of view of cost, the higher the speed the better. But there is a limit beyond which it is impossible to go, and a lower limit where the line ought to be drawn if due regard is paid to the ideal conditions of durability. Again, in the matter of working steam pressure, the same considerations would be given weight. Experience shows that extreme pressures are carried at a sacrifice of durability. All parts of the plant, starting with the boiler and following the piping to the engine, deteriorate at a much more rapid pace under high pressures, notwithstanding the fact that they may be designed for such extreme service. Whether this is also true of highly superheated steam is still to be definitely proved. The ideal plant must be constructed with these limitations in view. Again, the matter of durability is an important consideration with reference to that large class of auxiliary apparatus and appliances which make up the complete outfit. Some of these are necessary to the convenient operation of the plant, while others must be regarded more in the nature of refinements than as necessities. Whatever they are, it is important that they should be durable and reliable, and not dependent for their working upon extremely careful attention. Unless these appliances are absolutely reliable in ordinary hands, they will soon drop out of use.

ELECTRICAL NOTES.

An advantage which the electric furnace has over combustion furnaces is that a great amount of heat can be developed in a compact and limited space and that the same degree of temperature can be attained whether the furnace is operated on a laboratory or on an industrial scale.

Fire-alarm signals have within the last few years assumed a position of considerable importance, owing to the growth of great cities, the increasing height of commercial buildings, and the large quantities of combustible material necessarily stored in the great centers of population. For the purpose of transmitting defined, but limited, items of information, for special instructions, or for making demands, innumerable electrical appliances have been designed; but there is a general tendency to replace such apparatus by telephones, which simply extend the range of speech, the natural method of intercommunication, to any distance, and which render these subsidiary aids unnecessary.

Artificial Gutta-Percha for Telegraph Cables.—The composition, due to Herr Adolf Gentsch, of Vienna, and adopted for the German telegraph cables, is a mixture of caoutchouc, and palm wax having the same point of fusion as caoutchouc. It melts at about 60 deg. C., while keeping its homogeneity; as an electric non-conductor, it has the same value as gutta-percha; it is, however, 35 per cent cheaper. Submarine cables connect the islands of Föhr, Norderney, and several others of the North Sea and the Baltic. All these cables have been tested at temperatures ranging between + 30 deg. and — 5 deg. C., and an isolation of 650 megohms has been registered.

Electrolytic Production of Chlorine and Alkali by the Mercury Process.—The diminution of the useful effect of the current in this process is due to the depolarizing action of the chlorine on the alkaline amalgam produced in the cell, says Herr Glaser in the Zeitschrift für Elektrochemie. The loss proceeding from the decomposition of the water is of less importance. In his experiments the maximum yield has been obtained when the mercury circulates in the cell with suitable speed or on employing a diaphragm. With a diaphragm it is necessary, for a good yield, to have recourse to larger currents, while without a diaphragm the same results are obtained with smaller currents. Thus, a current of 0.1 ampere per square centimeter of cathode has given good results in certain experiments without the employment of a diaphragm.

Electrolytic Manufacture of White Lead.—Herr Borchers describes in the Zeitschrift für Elektrochemie a plant for the electrolytic production of white lead by the Luckow process at Wengerohr, Germany. It embraces ten tanks, each containing 12 anodes and 13 cathodes, 0.80 meter in width and 0.30 meter in height, or a surface of about 6 square meters of anode per tank. In all, 140 amperes are employed, at 14 volts tension, including loss. The electrolytes are composed of 3 per cent solutions as a maximum, but the best results are obtained with solutions of 1.5 per cent. These solutions contain 90 per cent of sodium chlorate and 10 per cent of carbonate. The electrolyte is kept in constant circulation. It flows to the upper part of the tanks between the electrodes, and has an exit at the bottom with the white lead. It is filtered, and the electrolyte, after saturation with carbonic acid, is conveyed back into the tanks. The yield at present is 3.5 to 4 kilogrammes per kilowatt hour. It is claimed that by the arrangement all secondary reactions are avoided, that both electrodes remain perfectly bright, and that no separation of spongy lead occurs.

Rapid Determination of the Purity of Sal-ammoniac Designed for Galvanic Elements.—To obtain good results with ammonium chloride, it is necessary that this salt should not contain too large a quantity of sodium chloride or of ammonium sulphate. M. Rosset recommends, in the French journals, a rapid test method consisting in the measurement of the lowering of temperature by the dissolution of the salt and the density of solutions of determined concentration. The density of the solutions of ammonium chloride is comparatively feeble, like that of all saline solutions obtained with strong absorption of heat. The density of a saturated solution of sal-ammoniac at 15 deg. C. is first measured. If this density is greater than 1.0766 (10.25 deg. Baumé), the salt is not pure. The presence of sulphate (of ammonium in particular) is then detected by precipitation with the aid of barium chloride. A solution of suitable strength is made, and the fall of temperature observed; then the density, when the temperature rises again to 15 deg. The lowering of temperature occurs in from ten to forty-five seconds; so it is necessary to operate rapidly. The influence of the external temperature may be neglected; but it is important to introduce the salt and the water at the same temperature. The method is sensitive and allows of the detection of small quantities of sodium chloride. Adulteration by the addition of inactive substances is ascertained by the fact that a part of the salt remains insoluble in the water. The addition of fixed salts is also apparent in the residue after sublimation of the salt in a porcelain dish. The sal-ammoniac should be as white as possible. A yellowish red tint indicates the presence of ferric salts. The presence of these salts is likewise detected by means of potassium ferrocyanide, which gives a blue coloration; or by ammonia, which occasions a reddish yellow precipitate. The presence of cupric salts is made known by the brown coloration produced by potassium ferrocyanide.

SCIENCE NOTES.

In grafting it would seem that seldom, if ever, do any characters of the stock pass into those of the scion except such characters as may be due to the presence of diffusible metabolic products, or products capable of self-propagation upon requisite stimulation. In this manner it has been shown that albinism may be transmitted from stock to scion. Again, Strasburger has indicated that atropin is accumulated in the potato when on a potato stock there is grafted a scion of *Datura stramonium*. It has been found that hardiness in the stock may affect the scion to a marked degree, but here the real problem is to determine what constitutes hardiness.

The Spots and Rotation of Mercury.—The first observations of the spots of Mercury date from 1800 and were made by Schroeter, Harding, and Bessel. They were observed by Prince in 1867, and by various others since. The periods of rotation deduced range from 24 hours to 24 h. 5 m. 30 s., but Schiaparelli evolved the hypothesis of a rotation of 88 days; that is one equal to that of the revolution of Mercury around the sun. The planet turns in the same way as the moon around the earth. Recently McHarg, in France, has deduced from the observation of a black spot a rotation of 24 h. 8 m. Besides this, he has calculated a rotation of 24 h. 5 m. 48s. from the observation of the Southern Horn.

Powdered Hydrogen Peroxide in Medical Practice.—Oxygenated water (hydrogen peroxide) is a powerful antiseptic, having the advantage over many products of this class of not being caustic or poisonous and of having no odor. Consequently it is coming more and more into use in surgery for the washing and disinfection of suppurated cavities, for purifying miasmatic and contagious centers, and for destroying microbes of all kinds. It is also an excellent hemostatic. A nasal hemorrhage can be immediately arrested by introducing in the nose wadding soaked with oxygenated water. Though it has these advantages, it is attended with an inconvenience; it is almost always acid, and thus somewhat irritating to the tissues. This effect is slight in many cases, and is remedied by rendering the agent alkaline at the time of its use with bicarbonate of soda. M. Joubert has discovered a method for the immediate production of non-acid oxygenated water, corresponding to the combination of oxygenated water with borate of soda. This is perborate of soda, which may be called a powder of hydrogen peroxide or oxygenated water. By placing this salt in water without the addition of an acid, a solution is obtained, which has all the properties of free and chemically pure oxygenated water and all those of borate of soda. It is alkaline oxygenated water, said to be capable of responding to all therapeutic needs and capable of being preserved indefinitely in the form of powder.

Dry wines in common parlance are understood to be those in which the sugar of the grape has through fermentation been converted into alcohol. These naturally divide into two groups, namely, red wines, such as clarets, burgundies, etc., and white wines, such as rieslings, hocks, etc. Red wines are made from colored grapes; a few varieties have colored juice, but in most varieties the coloring matter is in the skins and is extracted from them during fermentation. The grapes are crushed (and in nearly all modern establishments stemmed) and put in fermenting vats, or casks, where, in order to develop the color as well as to extract certain ingredients that give red wines their value, the crushed grapes are fermented—skins, pulp, and juice together. The use of selected yeast cultures to start and correct fermentation, as well as to improve the quality of the wine made, is destined to become an important factor in dry-wine making. The juice is not drawn off until the first fermentation is completed. In order that fermentation may be uniform the entire quantity in a tank should be crushed the same day. The vats should not be more than three-fourths full, else they are apt to run over during fermentation. The fermenting tanks are generally made of wood, although masonry is sometimes employed. Tanks made of either of these materials, before being used, should be carefully cleaned and before being used for the first time should be steamed for several hours. The size and number of the vats used will depend upon the quantity of grapes crushed per day. The vats vary in size from 100 to 10,000 gallons or more each. Enough of them should be provided so that, when wine making has commenced, it can be carried on without interruption until the grapes are all crushed. The tanks are set on skids, raising them about 20 inches above the floor of the room, and are set slightly higher in the rear so as to permit them to be easily drained from the front through a faucet inserted in a hole bored two or three inches above the bottom of the tank. A coarse strainer of some kind should be put over this hole on the inside of the vat, before it is filled, so as to keep back the pomace while the juice is being drained. Quite a diversity of opinion exists among makers of excellent wine as to whether it is best to ferment in an open vat, a vat loosely covered, or a vat hermetically sealed, having a safety valve or pipe discharging the carbonic-acid gas into a vessel of water, thus completely preventing contact with the air; also as to whether it is better to have false heads resting directly upon and fastened over the pomace or to stir the pomace. Good wines are made by either method.

TRADE NOTES AND FORMULÆ.

Transparent Cement for Glass.—Digest for a week, cold, 1 part by weight of caoutchouc, 67 parts of chloroform, and 40 parts of gum mastic.—Nouvelles Scientifiques.

Cleaning of Objects of Aluminium.—To restore brilliancy to tarnished articles of aluminium, it is sufficient to immerse them for a longer or shorter time in water slightly acidulated with sulphuric acid. For small objects, apply a soft brush and dip it in a weak solution of carbonate of soda.—Science Pratique.

Cement for Iron.—This is composed of ten parts of iron dust or filings in three parts of chloride of lime. Water is added to make a suitable paste, and when applied, the two parts are pressed together. Generally about twelve hours are required for complete setting.—Formulaire.

Oil Resisting the Temperatures of Superheating.—Expose at a high temperature the neutral fats extracted from wool, such as crude lanoline or wool wax, employing them either alone or in combination with mineral oils. The best course is to treat them in presence of superheated steam at a temperature of 300 deg. C. under a pressure of 50 atmospheres.—Chemische Zeitung.

Removal of Rust from Nickel Objects.—First, cover the objects with grease, and in three or four days rub them with a rag soaked in ammonia. This will dissolve the rust without attacking the nickel. If the rust resists this treatment, apply a little chlorhydric acid, and immediately afterward rub with a cloth, so that the nickeling may not be affected. Then wash, dry well, and polish.—Chemiker Zeitung.

Production of Strong Glue.—The Chemische Zeitung recommends this method: Make use of sulphurous acid to remove the phosphate from the lime of bones, employing an aqueous solution under pressure. The solution of the lime is produced rapidly without troublesome precipitation of calcium sulphite, and a simple distillation restores the sulphurous acid, separating it from the solution.

To Develop Old Manuscripts.—We use the photographic expression because we think it appropriate, as manuscripts become so often completely illegible. This fact is rendered apparent by a recent incident at the library of Breslau. The manuscripts had been written with ink having a base of nutgalls. They were covered with an alcoholic solution of 1 per cent of tannic acid and then treated with ammonia.—Nouvelles Scientifiques.

Silvering of Wood and Metals.—Melt 24 grammes of pure tin in an iron spoon and add the same quantity of bismuth. Stir with an iron wire until all is melted. Take from the fire, add 24 grammes of mercury, mix thoroughly and pour the mixture on a stone for cooling. When used, dilute with the white of egg, gilders' vermilion, or alcohol, to which a little gum arabic has been added. After applying, polish the objects.—Moniteur Bijoutérie et Horlogérie.

Chinese Cement.—This is a kind of glue very much used in China and is quite successful in fastening small objects. The ingredients are 3 parts of ammoniacal gum, 24 parts of Brazil fish glue, 48 parts of distilled water, and 96 parts of wood alcohol. A third of the wood alcohol is first added to the water in which the fish glue has been dissolved under a gentle heat. Then the gum is dissolved in the remainder of the alcohol and added to the first solution.—Science Pratique.

The Poetter Explosive Compound.—For this preparation there are mixed intimately 82.7 parts of nitrate of ammonia, 1 part of di-nitro-benzol, 11.5 of curcuma and 4.8 parts of oxalate of copper. The proportions of this mixture may be modified, according to the greater or less force of decomposition, or the greater or less atmospheric security desired. The advantages of the compound are said to consist in great security with reference to the atmospheric state and to the charcoal dust, while still having a strong decomposing force and an extremely reduced sensitiveness to the action of moisture.

To Get Rid of Ants.—Various receipts and processes have been published as a remedy against the invasion of ants. Here is one which is said to have given complete satisfaction. In closets and other places infested put pieces of moldy lemon. They must be thoroughly affected by the mold. It is not enough to cut up the lemon and leave it where desired. It will simply dry. The pieces should be left in a cellar until they are thoroughly covered with mold. When there is a green layer they are in fit condition for acting effectively. The odor, which somewhat resembles that of sulphuric acid, will completely drive off the insects in a couple of days.—Cor. Nouvelles Scientifiques.

Waterproof Cement for Leather, Caoutchouc, Balata, etc.—Such ingredients as gutta percha, caoutchouc, benzoin, gum lac, and mastic, may be dissolved in a suitable solvent, such as carbon bisulphide, chloroform, ether, or alcohol; preferably gutta percha or mastic is used, dissolved in carbon bisulphide or ether. When the solutions are ready, mix a quantity of one with a quantity of the other and boil the mixture, placing the receiver containing it in a receiver containing hot water. The boiling is important; the final result depending largely upon it. The following proportions are recommended by the patentee, M. Person: 200 to 300 grammes of gutta percha for 100 grammes of bisulphide, and 75 to 85 grammes of mastic for 100 grammes of ether. Mix from 5 to 8 parts of the solution of gutta percha with 1 part of the mastic.—Rev. des Prod. Chim.

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